

Risk assessment of a wind farm

[Economics](#), [Insurance](#)



1. 0 Introduction

1. 1 Preamble

This section of the report presents the background of the wind farm project, in particular offshore wind farm development, objectives, scope of work and the layout of the thesis

1. 2 Background

1. 2. 1 Wind farm

Although offshore wind farm development commenced decades after the onshore but recently offshore wind farm development seeing a dramatic growth due to the following reasons:

Availability of unlimited areas

Continuous or better supply of wind resources

Need for a bigger capacity

Environmentally friendly (eg; noiepollutionetc.)

This would also bring further challenges to the industry. For example, European wind association stated that Germany has installed first far-shore wind farm, Alpha Ventus, with a capacity of 600MW. Although this would increase the revenue of the wind farm companies, the installation costs are high too. Meaning that wind farm companies are forced to secure more capital form investors, which in current financial market is not that easy. Further the distance form shore the higher the water depth hence deeper the foundation and bigger the structure. This would present further challenges in terms of managing the risks.

It has been reported that wind power capacity has been increased to 38GW in 2009 to a total capacity of 160 GW and global capacity doubled during last three years to 2009, where China led the way [1]. It should be noted that in 2004 China only produced 2% of the world capacity but today almost accounts for 20% of the world's wind capacity. United States, China, Germany, Spain and India produce almost half of the existing wind capacity. The other leading countries include Italy, United Kingdom, France, Portugal and Denmark [1] However the offshore wind industry is slightly lagging and only produces 2GW and the trend is definitely changing to the right, due to lack of suitable onshore locations and pollution aspects (noise). Eleven countries have offshore wind farms and the United Kingdom is leading its way by passing 1 GW wind capacity in 2010. Offshore wind farm development is expected to grow around 35 GW by 2020, worldwide.

Also, almost 97% of the offshore wind farms are located in European waters and in 2009 a total of 75% offshore capacity was bought online and it is mainly procured by utilities companies.

It is apparent that since the commission of world's first wind farm the development of wind farms has increased dramatically across world. As an example during early days (eg: Scurry sands) wind turbine capacity of 2MW against the latest capacity of 5MW (Alpha Ventus). Not only the capacity of wind turbines has increased but also the hub height, rotor diameter and water depth at the installation. This meant that inherent hazards have also increased significantly.

1. 2. 2 Insurance

Insurance plays a vital part in wind farm projects due to the very nature of the development. European insurance market normally provides insurance for wind farm operators and related service providers. There are many companies specialise in wind farm insurance and normally provide Property Damage (PD) and Third Party Liability (TPL), Construction All Risks (CAR) and Business Interruption (BI) overages. Insurance company would pay out any damages to the property, loss of production or liability due to named peril on the policy. Although insurance market is very mature, the wind farm related insurance is still in its infancy and many insurers are still learning on how to underwrite wind farm insurance profitably.

Wear and tear is a routine damage to wind turbines but they also suffer from corrosion, fatigue and impact damage. Also, there will be losses due to natural peril such as: wind, lightening, earthquake etc. These damages, depends on the nature, would trigger property damage, liabilities and business interruption to the insurance industry. It should be also noted that there still exist some technical issues in the construction wind farm projects.

A Number of wind farm project operators approach local insurance market for the traditional Property Damage (PD) and Third Party Liability (TPL) for insurance purposes. And depend on the insurance capacity (ie, capital) local insurance carriers fulfil the objectives. In recent years, due to the exponential growth in the wind energy market companies are developing bigger wind farms with bigger capacity and at a bigger scale; the local insurance carriers are not capable of providing coverage due to the available insurance capacity. This meant London and European insurance market is

seeing phenomenal growth in the wind farm energy related insurance requests. Also, London insurance market provide additional coverage; such as Delayed Start Up (DSU) or Business Interruption (BI) or Construction all risks (CAR) at a bigger capacity level.

Further, insurance companies require to have Standard and Poor (S&P) rating of A- or A. M. Best rating of A-, in order to satisfy the lenders requirement for lending. S&P is a well recognised rating agency that goes through a thorough vetting procedure of any financial institution and rates them accordingly. Many lenders and corporate companies make a prerequisite of S&P A- rating before lending or buying insurance. An insurance company with good rating would pay up any legitimate losses without any major delays. Claim payment is very crucial in wind farm development, as many investors borrow money to invest and would like to see the capital is protected. This meant many local insurers will struggle to fulfil the requirement of S &P, especially from developing countries. Therefore many local insurers arrange a fronting arrangement with European insurance companies to provide cover for their local market.

Insurance industry has witnessed a number wind farm projects during last 15 years and unfortunately had to pay out huge amount in claims. However these claims of small in nature compared to traditional Oil & Gas claims. However, numbers of occurrences are high [15].

Further, due to the very nature of the insurance market not much technical engineering information is requested prior to underwriting a wind risk. As a consequence, the insurance industry suffered immensely during early days,

where mainly decision was made by underwriters who have no technical knowledge of the subject. However, lately the market in general demands for more engineering information prior to underwriting. It is evident that leading insurers such as: Swiss Re, Zurich, Munich Re, Liberty, Allianz and Torus are heavily investing in employing seasoned engineers to identify the real engineering issues before underwriting.

Although there are several literature on identifying the risk in wind farm projects but very few related to the insurance sector. There are some underwriting firms have developed their internal risk assessment tools for their internal use but not in detail as presented in this research.

1. 3 Objective

The main objective of this research is to better understand inherent risk levels in the wind farm project, particularly in the offshore sector and to differentiate the risk levels in order to make a better underwriting decision.

1. 4 Scope

The scope of the project is to:

Undertake literature review on wind farm risk assessments, existing financial instruments such as wind derivative, Credit Delivery Guarantee (CDG) and Climate Emission Reductions (CER). Wind farm related losses will also be reviewed and summarised.

Identify the associated inherent risk levels on wind farm projects during construction and installation phase and the operational phase

Create a risk assessment tool incorporating above risks

Discuss available financial instrument and their use to the wind farm risk management

Establish a mechanism to manage the risk level and devise a product that would be appealing for the client

1. 5 Layout of the Thesis

This section of the report describes the background of offshore wind farms and the objective and scope of the project. Section 2 describes the related work on offshore wind farm risks assessments. Whist Section 4 describes the risk assessment of wind farm in detail Section 5 presents the conclusions and recommendations of the study. Section 6 lists all the references that have been used in this study.

2. 0 Literature Review

2. 1 Introduction

This section of the report summarises the literature review that has been performed on wind farm and its associated risks, which are relevant to this study. Further, wind farm related losses have been reviewed and summarised.

Literature review is undertaken in three parts namely: Wind farm risk assessments, financial instruments that are available and losses and failures that are related to wind farms.

The current challenges that off shore wind farm faces are:

Design of wind turbine designs and its reliability

Geotechnical conditions including foundation design

Installation vessels and its capabilities

Manufacturing contractors and their reputation

Offshore cabling

Operations and maintenance programme

Health and Safety issues

Electrical transformer stations

Suitability of Financial instruments to manage the risk

2. 1 Background

This section of the report summarises the main components of the wind farm and its background information.

Johnson stated in his book that Denmark was the first country to use wind turbines to generate electricity and a very first wind turbine was installed in 1890. The diameter of the wind turbine was 23 meters. Also, a number of small wind turbines with a maximum capacity of 25MW were in operation by 1910[22].

Offshore wind farm consists of four major components, namely; foundation, tower section, turbine and transition piece. The major component of the wind turbine is shown in Figure 1.

Turbine is made up of several components and all components are cased in nacelle. Gear box, shafts and generators are the other main components of the turbine. When wind blows, blades start to rotate and shafts will rotate

and electricity would be generated and will be transmitted through the cable to the transformer and the grid. Figure 1: Main components of wind turbine (information purposes only and not to scale)

Tower section of the wind turbine is made up of steel and conical shape. Turbine is rigidly connected to the Tower section and tower section itself is connected to the transition piece. A transition piece has a small access platform. Transition piece is directly connected to the monopile by a grouted connection.

2. 1. 1 Foundations

Offshore wind farms foundations play very critical role in design of wind farms. The choice of foundation depends on the water depth of the location and the capacity of wind turbine. Typically foundation comes in four major categories and they are:

Gravity Foundation – These foundations are made of reinforced concrete and suitable for water depth up to 30m and beyond that water will prove uneconomical. This foundation will take up to 5 MW turbines and the design has been proved to be a very effective design.

Monopile foundation –

This foundation is made up steel tubes at various sizes and suitable of water depth up to 25 meters. This is well established design most favoured by designers and clients due to it's simplicity but only limited to 3. 6 MW turbines.

Tripod Foundation – This type of foundation are heavy steel structures and suitable up to 35 meters water depth. Also it can accommodate 5 MW turbines. The only issue with this technology is only limited experience with this technology. However, offshore industry has utilized this technology for a very long time.

Jacket Structure – As with Tripod foundation these are heavy lattice type of structures and can accommodate heavy turbines. Also, this foundation can be deployed at greater water depths.

Further, soil studies also plays an important role in wind farm projects. It is normal to obtain a borehole data prior to installing piles. Using the borehole data soil strength would be achieved and will be compared with the design load of the wind farm project and if the design load is less than the soil capacity foundation is said to be adequate. It is recommended that minimum safety factor two should be achieved for operating conditions of the platform.

For foundation structures analyses should be undertaken to satisfy operating condition and extreme wave conditions. Extreme conditions are typically of 100 year return periods. In addition to the strength analysis fatigue calculations should be undertaken to fulfil twice the size of the design life of the structures.

2.1.2 Cables

One of the common problems in offshore wind sector is the risk associated with cables, which includes anchor damage from vessels, fishing trawler damage, sea motion and material damage, abrasion and reliability. This can be minimized by making sensible and well calculated routing calculations,

protection of cables either by burial or concrete mat protection, dedicated wearing systems, appropriate design of cable/turbine interface and ample enough redundancies in the system.

It should also be noted that authorities sometimes do not allow trenching and jetting to be undertaken due to environmental consideration and instead require a deep burial of cables at a depth of 2 to 3 meters. Meaning that, clients were very often forced to work in harsh weather windows to fulfil their contract obligation

In addition, there will be operational challenges such as quality of the sea bed survey, weather and sea state conditions, shore landings, transfer of people and cable pulling through tower structure. This would raise the project risk levels to high.

2. 2 Literature review

Larsson has undertaken a comprehensive work on wind turbine and the main findings are as follows [8]:

A comprehensive assessment has been carried out on various type of wind turbines and the quality of the power where he has concluded that fluctuations caused by turbine may cause flicker disturbances.

Compared fixed-speed turbines and variable-speed turbine and the effect on power quality.

Cable reliability was studied by Takoudis[12] in depth where he reviewed failure rates of cables and electrical systems and assessed its reliability using Monte Carlo simulation. Main conclusions were: Although

many studies were undertaken to study the reliability of the cable there still exist some issues and certainly there should be redundancy consideration during design of offshore wind project.

Carryer et al, studied the environmental risk for offshore wind farm both by the wind farm to the environment and from the environment to the wind farm and concluded that careful planning and regulatory involvement is critical. The author has also identified marine conditions, fishing, wild life and maintenance of the wind farms as key factors.

The effect of sea ice and icing on the turbine was studied in detail by Battisti et al [16]. The author has also studied the effect on floating ice on the structure and concluded that the ice loads will create additional vibration load to the structure and as a result life span of the structure may be affected. Further, ice mitigation systems such as: anti-freeze devices, reducing the sea actions should be implemented. Some countries have adapted a proactive approach to this issue for example, German and Danish regulatory authorities have addressed by stating that integrity of the wind farm structure should be checked for both extreme conditions including ice loading.

A study by Anderson revealed that clean energy in the last two decades has become a very competitive clean energy production and it will also fulfil a considerable amount of demand of many countries. He has also concluded that wind farm development will become as important as nuclear power in the future.

Further, several insurance submissions have been reviewed by various operators and the following summary was noted:

Severe weather: weather conditions are very important in the operational of offshore wind farms. These are typically wind, wave, lightening and earthquake. Excessive winds may affect the production electricity, as wind farm will automatically shut if wind speed exceeds certain threshold. Waves could be very damaging to the wind farm structures high waves may create wave impact forces on the structure and platform and may result in total failure. Earthquake will create inertia forces and will cause the structure to fail. If a structure is to be built on earthquake prone area it is important to design wind farms as earthquake resistant for at east 1000 year return period.

All the above risks can be minimized if all factors are considered and incorporated at design stages.

Lack of wind energy: This is mainly related to wind derivative and it is independent to the insurance product.

Third party verification: This is very important in any design or construction project. It is of utmost importance that all design calculations, drawings, installation procedures, load out procedures need to be verified by an independent third party. For construction projects normally warranty surveyor will be appointed by the underwriters to oversee the construction work and verify all their procedures and require their attendance for certain

activities. Therefore it is always important to appoint a reputable warranty surveyor for the tasks.

2. 2 Wind turbine and wind farm loss history

Woebbeking [5] summarised all wind farm related losses thus far and in particular summarised some main findings from the lessons learnt exercise:

He compared 2500 datasets wind turbine failures and found that 26% due to gearbox failure, 17% due to generator/bearings failure, 13 % due to drive train, 19 % due to electrical installation and the 25% due to other factor.

Morgan et al [10] analysed the impact of ice loading on wind turbine and public safety. They concluded that special turbine features to be implemented and also public should be taught with relevant warning signs. Ice Accretion would also cause property damage to the blade as well as if somebody hurt potential liabilities issue may follow.

Also Willis loss database identifies losses in the insurance industry; where it identifies losses above \$1 million threshold.

Caithness wind farm Forum [17], based on reported and documented cases, produced wind turbine losses from 1995 to date and the summary is as follows:

A total of 994 incidents have been reported since 1970. Seventy of them are fatal accidents which caused 78 fatalities. Out of 78 accidents 55 were directly related to wind industry personnel and 23 were public. Another 79 accidents regarding human injury is well documented and many more not

documented.

The biggest accidents are due to blade failure. Blade failure occurs due to fatigue or bird strike and there were 203 reported cases on this very issue. The report also summarises the blades were travelling up to 1300 meters and believe 2km buffer zone should be in place.

Another common one was the fire and it is the second most common accident totalling 158. The main threat here is the consequences of the fire from one turbine. On harsh weather conditions this would create forest fires and also fire to the other turbine by flying debris.

Third common accidents are due to structural failure which totals about 112 incidents. These failures were mainly due to the fact that they don't withstand design conditions, especially damage to turbines and collapse to towers. Although structural failures tend to create high claim for the insurance industry (PD) the liability claim (eg: human health) tend to be lower.

A total of 31 ice throw incidents were recorded and can reach up to 140m. There have been 70 reported accidents while wind turbines on transport. Another 185 general type of accidents such as component failure, lack of maintenance, electrical failure, construction and lightening strikes have also been reported.

The report also warns that those accidents were only a portion of a big percentage and the trend is certainly arising. There is also public safety concern and there should be an safe exclusion zone of 2km for the wind farms.

2. 2 Wind farm Risk Assessment

It has also been observed that many financial institutions are investing or lending money to the development renewable projects. Investment has grown from \$22 billion in 2002 to \$155 billion in 2008[19.]

UNEP study [9] identifies more than twenty critical risk factors in terms of its importance some are listed below:

Contract bankability – project unable to secure bankable, offtaker contracts. This is normally a precondition for the lenders and the expected cost might soar during the development of the project and there is a high risk offtaker may not fulfil the contract if price rockets.

Warranty non-performance – turbine manufacturers' obligation to meet the warranty requirement. Due to heavy expansion of wind farm projects there may be some issues servicing the need for the client. Which in turn, would certainly impact the insurance industry by paying more on BI policy.

Offtaker default – electricity off taker defaulting on contractual obligations under power purchase agreement (PPA) once in operating phase. PPA usually provide a long-term stability to the company and if broken finding an alternative purchaser could prove very difficult. This would be more difficult if the purchaser had a monopoly on the area or certain country. To eliminate this issue company buys a political insurance.

Technical engineering hazards – defects at the design stage and wrong choice of material, workmanship is not up to the standard etc.

Also, the report summarizes the wind farm risks as five major parts namely: contractual, operational, Clean Development Mechanisms (CDM) related, Physical hazards and additional risk.

It has been reported that if full suite of traditional insurance coverage is obtained during construction and operational phases the default rate would reduce from 7.48% to 1.18%[14].

2.3 Risk transfer mechanism and financial instruments

Financial instruments are becoming very popular emerging tools to manage risk in the wind farm industry. Traditional insurance product may cover some aspects of risks associated with the wind farm but also wind derivatives; credit delivery guarantees (CDG) and certified emission reduction (CER) future contract assist to mitigate the risk levels.

Wind derivative can be treated as an insurance policy, a reinsurance treaty or form part of financial contract. It is a financial instrument, designed to protect clients against abnormal weather conditions. The wind derivative can be obtained from the insurance sector. It is an index based cover where measured wind speed as an underlying index. If the wind speed is less than index value and the production falls beyond an agreed threshold, policy will trigger. These instruments are traded on financial markets and are usually designed to energy sectors to hedge against abnormal seasonal variations. Wind derivative can be explained by the following example:

Credit Delivery Guarantee (CDG): CER financial issues can be addressed by CDG and may include additional CER related delivery risks [1]. A CDG is

offered by a selected group of insurers to the clients, who have emission reduction credits generated from Kyoto projects (clean development mechanism). The product is designed to protect the clients from credit delivery shortage and failure arising from forward purchase agreements [14]. Further CDG product would typically cover: credit risk, political risk, Kyoto regulatory risk, and technology performance risk and business interruption. The study also revealed that CDG could add additional confidence to the market and buyers would be prepared to pay premium on CER prices. This would give a boost to cash flow at the front end of the project.

UNEP study[14] has also concluded the following for non traditional instruments:

Political risk insurance typically would cover off taker default, political unrest. If included would have a positive impact on the default and debt rating. Warranty insurance is designed to offload manufacturer's liabilities but this product is still in its infancy

When traditional insurance coverage is combined with political insurance, CER futures default rate would come down from 7.48% to 0.54%

CER future contracts: The risk of market volatility is normally addressed by CER future contracts. This would be established as a put option with a strike price. This option will give the buyer to sell the share of CER at a future agreed date and the strike price [1].

UNEP study [9] also reveals that non-traditional risks can be managed by wind powered derivative, credit delivery guarantees and CER future

contracts. The study has also identified possible financial risks and any financial risk management instruments available in the current market. The known wind farm risks and the available mitigation measures are listed in Table 1.

Risk	Project Phase	Financial risk instrument
Contract bankability	Development	No
Warranty non-performance	Operation	Warranty insurance
Off taker default	Operation	Political risk insurance
Engineering Risks	Construction	Construction all Risks (CAR)
Physical hazard	Construction/operation	Construction all Risks (CAR)
Natural hazard	Operation	Property Damage (PD)
Offtaker contract failure	Construction	No
Catastrophic design failure	Construction	No
Permitting Planning delays	Development	No
CER bank ability	Development	CDG
Wind volatility	Operation	Wind power derivative
Process Interruption	Operation	No
Legal Liability	Operation	Third party Liability
CER insolvency, regulatory, political and performance risk	Operation	CDG
Design/ equipment mal function	Operation	Machinery breakdown
Long term CER marketability	Operation	Futures contract

Table 1 Wind Farm Risks and its Nature

It is very clear that although there are several financial instruments available in the market but there are still some gaps in the risk management. It is

important that every risk can be identified and managed in systematic manner all stake holders would benefit in the long run.

Further a study by UNEP, Marsh finances et al [13], explored three financial instruments which could be applicable for large scale wind farms and they are namely: Standard wind derivative, Wind reserve and wind swap. They developed based on wind derivative and calibrated specifically as credit enhancing instruments. The main findings of their study were:

Standard wind derivatives have been well established in the market and are very expensive hedging instruments

Wind swap is a product with a low premium but if the wind conditions are favourable, the client is required to pay back part of profit revenue

Wind reserve has also low premium like wind swap but does not require to pay back the upside revenue if weather conditions are favourable. Instead part of the cash is invested in a reserve account for maximum of 12 months hence does not reduce the equity return. Further, lenders were happy to increase the debt leverage when wind reserves are in place.

2. 4 Summary

Following on from the literature review it is clear that there are three major risk elements are associated with the wind farm projects and they are:

Construction

Operation

Contractual and financial

First two are directly related to the current insurance market and the third one is although slightly independent to current insurance product but mostly will affect the investors and the operators of wind farm. By combining the traditional insurance package and non traditional financial element packages, all stake holders will benefit in the long run.

3. 0 Method of Research

3. 1 Introduction

This section of the report describes the research method. Section 1. 2 is a brief summary of interview questions and its findings and Section 3. 2 summarizes the method for the research

3. 2 Method

An interview has been carried out within an insurance provider, about wind farm risk and their perception on risk management. Following questions have been asked on offshore wind farm project:

Can your company underwrite the wind farm risk

What is your perception of wind farm risk

What is wind farm's strength and weaknesses

Would you consider wind farm project as viable option

Can your company be profitable by underwriting this type of risk

A major part of the process is undertaking interview with the following personnel:

Engineer

Underwriter

Actuary

Claims adjuster

CAT Modeller

The results were analyzed in detail and it is summarized below:

wind farm project is not a viable option for the company in terms of profits

Wind farm projects had series of claims in the last decade or so

Technology is still it's infancy and require more scrutiny

Although there are lots of strengths such as: sustainability, environmentally friendly etc, associated within wind farm development but main weaknesses

are the number of claims and loss ratio is more than one. In addition

insurance sector never made profit from underwriting wind risks

The insurance premium of wind farm risks is very low compared to the

traditional offshore oil and gas projects. Although risks are less in operational risk the construction risks are almost similar.

The wind farm project would certainly an option if the company can better understand the risks and can price the risk accordingly.

Company can be profitable by writing wind risks, firstly if we understand technical issues by undertaking engineering assessment; secondly

benchmarking different projects and finally pricing each risks separately in terms of risk levels and exposure.

It is apparent that the insurance industry's underwriters have major doubts in wind related risks. Also at present, there is lack of knowledge in the

insurance industry with regard to technical issues involved in the wind farm projects. Therefore it is vital to undertake a risk assessment before underwriting the account. Based on the risk assessment the policy can be priced accordingly with appropriate deductibles and policy limits. In the next section all risk factors which contribute to the integrity of the wind farm project will be discussed.

Following on from the detail literature review and based on discussions within the company personnel a plan has been devised and presented below:

Development of separate risk rating tools for construction and operational phase. This would typically comprise the following risk factors:

Assessment of design and fabricator contractor's experience – a thorough and comprehensive assessment would be undertaken on key personnel's experience, previous experience and success rate.

Assessment of construction methods – all typical construction methods will be reviewed in terms of associated risks.

Assessment of installation contractors' experience – this would be normally assessed by reviewing their suitability for the job and also their track record.

Assessment of installation vessels – depending on offshore specific vessels will be vetted thoroughly.

Assessment of project complexity – connecting to existing power grids, umbilical crossings, third part interest etc.

Assessment of third party exposures; fishing, ship impact and air craft.

Assessment of environmental criteria including natural perils; windstorm, tsunami, earthquake etc.

Assessment of supply chain, marketability, loss histories (insurance) of the client.

Available financial instruments which can be utilised in the insurance industry

Development of credible insurance package for the client base, predominantly on risk assessments with coverage from natural perils to all risks.

4. 0 Risk Assessment

4. 1 Introduction

This section of the report discusses and presents two different risk assessment models for construction phase for the wind turbine and operational phase of the wind turbine. Further all risk factors will be discussed in detail.

4. 2 Risk Factors

Major engineering hazards in the offshore wind farm sectors are classified in terms of Excellent, Good, Above Average, Average, Below Average and Poor. The aim is to capture all risk factors and rate them individually and weight them out of 100. Then each component of the risk will be added according to their weighting. For example if all risk factors are rated as 'excellent' the assessment tool will assign a score of 100. And if all risk factors are rated as 'poor' the score will be 0. In addition, the overall account will also be rated based on the definition as shown in Table 2.

Rating

Score

Definition

Good > 80 The very best of current day practice in the industry; an industry leader.

Above Average 65 – 80 Exemplifies some of the best practices in the industry.

Average 50-65 Acceptable standards exhibited, but with room for improvement.

Below Average 40 – 50 Some areas are below the standard of current day practice, with considerable potential for improvement.

Poor < 40 Embodies few or none of the standards expected of current day practice, with major improvements required

Table 2: Risk Rating Score definition

For example, if a total score is less than 40, the system would give an overall rating of poor. Meaning that, it is badly maintained and badly designed project with substandard contractors and fabricators. These score will then form part an underwriting decision making tool together with pricing strategies.

4. 2. 1 Construction phase

A number of risks are related to wind farm construction and the critical ones are discussed in this section.

Design issues such as lack of detail engineering – This is basically meant all design whether it a new or a proven technology, require attention to detail and follow internal or regulatory procedures. As an underwriter it is

important that all designs calculations and processes are adhered to well recognised procedures.

Experienced personnel – Experience of the designers is the key in construction projects. As an example, well published Gulf of Mexico Mcando well blow out incident also partly blamed the inexperience crew on site. Therefore it is crucial to identify and evaluate the experience of the engineers, technicians and the other key positions prior underwriting an account.

Fabrication issues – For construction of wind farm, it is important to find whether particular yard has previous experience in constructing wind farm sub-structures. Further, it is important to make an assessment on the lay out of the fabrication yard to identify any fire hazards etc. It is also of utmost importance that material strength needs to be checked in accordance with industry standards, eg: DNV and the random samples of the materials should be tested periodically during the fabrication. In addition, regular inspection of site by experienced personnel may reduce the risk of poor workmanship.

Fabrication yard fire: This risk is always present and as mitigation it is important that fire fighting systems and fire water supply are in place and there is a dedicated crew on site to tackle an unforeseen event. Also, it would be useful to obtain the information on fire drills and how they are conducted.

Load out from the fabrication yard to installation vessel – Load out is considered to be very critical and most accidents occur during load out

stages. Risks can be minimized by following well established procedures and undertaking HAZOPs and HAZIDs at each critical level. As an underwriter it would be useful if the client can submit all relevant documentation.

Natural hazards: This includes wind, wave and earthquake both at the fabrication yard and during transportation and installation phases. This can be minimized by identifying severe weather period for a given location. For example, if wind farm are being installed in North Sea in the UK, it is of utmost importance that as far as possible winter period should be avoided because North Sea is well known for its harsh weather (both in terms of wind and waves) during winter period.

In addition, earthquakes and tsunamis are also bigger threat for fabrication yard. There are several established weather map available for almost all world wide location and need to be referred. One such example is Munich Re map[20].

Suitability of installation vessel: This is mainly concerned with the installation vessels and jack-ups are normally used for this type of activity. Jack-ups normally susceptible for punch through while jacking up. It is important to audit contractor's safety systems prior signing any contract. There are several instances jack-up damaged due to punch trough and as a result client has to trigger the DSU policy. Therefore it is advisable to have another vessel with similar characteristic within the vicinity.

Dropped object during installation: This is most common problem is construction phase. Normally dropped object will damage subsea pipelines

and cables. A thorough vetting of crane and installation vessels would assist to understand the issues.

Loss of cargo while transit: This meant issues with transportation contractor and vessels' capability. The contractors' reputation is the key in determining the risk. Contractor reputation can be easily assessed based on their previous work and incidents.

Loss of production (Delayed Start up): This coverage normally triggers if there is any unexpected delays due to material/parts unavailability or hold up in fabrication program. This can be minimized if the client plans the project effectively including contingency plans where redundancies are identified clearly. Any critical path should have been gone through a thorough due diligence prior to implementation.

4. 2. 2 Risk Quality Rating

In this section Risk Quality Rating (RQR) assessment will be discussed. Two different assessment tools have been developed to assess risk levels for the wind farm: one is for the construction phase and the other one for an operational phase. The aim of developing the tool is to risk assess each and every account using a consistent approach and to differentiate the quality of the risk and to price the risk accordingly.

Based on the previous section risk factors are identified and categorised into main and sub categories as listed below. For each category is weighted out of 100. Each sub category is assessed individually and rated accordingly. Then overall account risk quality score will be calculated out of 100.

Main Category

Sub Category

Weighting

Site Location & LayoutSite Layout Configuration Exposure15%

Foundation Design

Structure Design

PML Severity

Project Hazards

Project Complexity15%

Technology Utilised

Original Equipment Manufacturer Guarantees/Warranties

Load-out/Installation/Commissioning Phase

Environmental Parameters

Water Depth10%

Ground Conditions

Wave Exposure & Mitigation Provisions

Windstorm Exposure & Mitigation Provisions

General Management

Completeness of Scope20%

Clarity of Documentation

Use of Established Procedures

Contractor Selection and Experience of Main Contractor

Level of QC and Management

Existence of Risk Assessment

Project Management

Project Management Structure10%

Project Schedule/ Bar Chart

Union/ Non- Union Workforce

Site Security

Plant & Equipment Security

Third Party Activities

Third Party Exposure10%

Geographic / Political Exposure

Construction Considerations

Use of Innovative/Complex Installations10%

Pre commissioning Observations

Marine Spread

Installation Vessels5%

Marine Vessels

Marine Procedures

Transportation Parameters

Fire Protection

Fire Fighting Provisions During Construction5%

Fire Fighting Provisions During Testing & Commissioning

Each sub categories is defined in preceding sections, where the definitions are tailored towards the rating ' good'. Any deviations form good will be rated accordingly. For example, if third party is rated as Average, only few of the items listed is fulfilled and the rest were either missing not presented.

Site Layout Configuration Exposure

The following are considered to be good practice:

Adequate plant spacing some minor consequential damage to be expected to other equipment within the plant following mechanical failure

Processes, operations or materials having an appreciable explosion hazard and a moderate fire hazard

Provision for on site storage of materials in separate storage and lay down areas

Good access for materials and equipment delivery some segregation

Good access for construction site and installation site

Foundation Design

Full geotechnical study conducted by contractor

Foundation design meets all recommendations of geotechnical study report

Anchors/Moorings are designed as per codes

Structure Design

All structural components are well designed in accordance with codes and meets minimum requirements. All process component facilities are well designed and meets minimum requirements.

Project Hazards

Probable Maximum Loss (PML) is less than 25% of total sum insured

Multiple construction work faces with little interdependency between work faces, units or plant

Technology Utilised

No prototypical or unproven equipment utilised

Configuration of equipment is proven

Similar plant already in operation

Original Equipment Manufacturer Guarantees/Warranties

OEM warranties cover faulty design, plan, material and specification of the faulty part only

OEM warranties are in effect during testing and commissioning period and during the maintenance period

Load-out/Installation/Commissioning

Adequate installation and commissioning plans are in place as per standard

Environmental Parameters

Water Depth – Suitability of the vessel for a given water depth. The deeper the water depth greater the risk.

Highly compacted load bearing surface

Soil type typically classified as well compacted clay

Areas which have a generally mild weather pattern for a significant part of the year. Such areas may be considered to be the Mediterranean, Red Sea and some areas of south east Asia.

Hurricane/ typhoons preparedness plan – Site has comprehensive hurricane preparedness plan. Materials are stored on site for preservation of property in the event of a windstorm. Physical defences will be constructed or are in place to protect the site from the storm surge associated by a category 4 hurricane such as raising the site level, sea walls and levees around the perimeter of the site. Areas which have a generally mild weather pattern for a significant part of the year. Such areas may be considered to be the Mediterranean, Red Sea and some areas of south east Asia.

General Management

Scope of project is well defined and complete

Documentation is clear and with controlled issues

Project Procedures are well established

Contractor has significant experience constructing projects in this region (i.e. Middle East / Asia / Latin America / North America / Europe)

Contractor has significant experience constructing projects of similar size and type

Contractor is known to engineers and previous projects have been well run with few if any losses

Contractors Quality Assurance (QA) / Quality Checks (QC) procedures are well developed and actively implemented on site

QC involves the use of recognised external inspectorsThe senior management has over 10 years experience in this type of project.

There is a documented Risk Assessment procedure for the project.

Project Management

Project Management Structure

Owner is actively involved in project management

Owner has significant experience managing EPC contractors and sub contractors

Owner has on site project management team including discipline engineers, QA/QC and HSE staff

Owner has head office engineering and project management back up and utilises third party engineering consultants

Project Schedule/ Bar Chart and reasonable time periods

Critical path identified with some amount of float for non critical path items project schedule based on maximum 6 day working week

minimal exposure to weather related delays (hurricane / cyclone / extreme cold) or schedule has allowed additional float to mitigate delays

Site Security

Perimeter fence installed prior to works commencing

Manned access points 24 hours per day

Site patrols by security guards during non working hours

The credentials of all persons entering the site are checked and the entry is recorded.

Third Party Activities

No third party surrounding property within 500m of site boundary: Shipping channels/Shipping density/Anchorages/Military Zones/Fishing

Intensity/Construction Activities/Sabotage

Stable government or sovereign state

No difficulties for personnel gaining access to country – Visa's not required prior to departure for EU Citizens

No difficulties bringing materials or equipment through customs

Adequate infrastructure minor road / bridge modifications along route required to transport large pieces of equipment from port of entry to site

No hijack / kidnap exposure

Construction Considerations

Straightforward project with previous examples in existence with operating experience.

Pre-commissioning Plans show no unusual hazards

Marine Spread

Main installation vessels have good track record

Marine vessels are well suited to the operation

Proper Marine Procedures are in place

Good Transportation Parameters for departure are established

Fire Protection

Fire fighting equipment and trained emergency response personnel are more than adequate for the anticipated hazards.

Fire fighting systems, and Fire and Gas detection systems, are in service and tested prior to introduction of hydrocarbons. Or alternative systems are to be in place. There is a fully trained emergency response team immediately available

A risk assessment tool detailing CAR risk And DSU risk is presented in Figure 1.

4. 2. 2 Operational phase:

For operational phase of the wind farm risks the following are considered:

Machinery breakdown – This is a most common defect in the operational phase of the wind farm. Most common being, gear box failure and the generator malfunction.

Material defects – It has been reported that grout connection between monopile and the transition piece is a major problem in the offshore wind farms. It is important to learn how client is dealing with this to minimize the effect on production. Insurance provider needs to learn the impact of this issue and how the client has learned from their past experience. It is always

good to see the client learning from their past mistakes (ie, lesson learnt) and rectifying in the future projects.

Foundation settlement / failures: Foundation settles over a time or suffers from scour. This can be easily rectified if a sea bed survey is performed prior to installation. Further a reputable designer would typically look at soil data to analyze the failure mechanism with almost 100% certainty.

Scour: This is a very serious problem in the offshore structures where heavy current cause's serious scour at seabed and foundation will be exposed.

There are number of ways that this could be minimized and such method is to called rock dumping. Rocks with certain diameter would be dumped near to the foundation to minimize the scour. In extreme cases additional skirting would be provided in the surrounding areas.

Anchor drag: This is a most common issue in the offshore wind farm projects. During early days cables have been lost due to anchor drags. At present if the water depth is lees than 50 meter there is a requirement to bury the pipeline/cables by at least 2-3meters. This is certainly a requirement in European waters but necessarily in the other part of the world and insurers should be aware of this very issue.

Dropped object: These are similar to construction phase of the project.

Cables are very vulnerable

Fire – There is always a risk due to fire and all systems should be tested and verified in accordance with fire safety regulations. There is also danger to the existing turbines as a result of damage by flying debris.

Impact – typically from ships losing control and supply boat impact and also birds strike.

Business interruption: This is mainly loss of production due to machinery breakdown or property damage to the wind farm. Following factor determine the BI part of the policy:

Redundancy of critical parts – It is important to know all relevant parts can be

Availability of peripheral vessel and the day rate

Down time – Production loss due to and an accident due to man, nature or a third party.

Availability of the experienced personnel – as same as construction

4. 2. 2 Risk Quality Rating

In this section Risk Quality Rating (RQR) for operational part will be discussed. Based on the previous section risk factors are identified and categorised into main and sub categories as listed below. For each category is weighted out of 100. Each sub category is assessed individually and rated accordingly. Then overlall account risk quality score will be calculated out of 100.

Main Category

Sub Category

Weighting

Site Location & LayoutSite Layout Configuration Exposure15%

Foundation Design

Structure Design

PML Severity

Project Hazards

Project Complexity15%

Technology Utilised

Original Equipment Manufacturer Guarantees/Warranties

Load-out/Installation/Commissioning Phase

Environmental Parameters

Water Depth10%

Ground Conditions

Wave Exposure & Mitigation Provisions

Windstorm Exposure & Mitigation Provisions

General Management

Completeness of Scope20%

Clarity of Documentation

Use of Established Procedures

Contractor Selection and Experience of Main Contractor

Level of QC and Management

Existence of Risk Assessment

Project Management

Project Management Structure10%

Project Schedule/ Bar Chart

Union/ Non- Union Workforce

Site Security

Plant & Equipment Security

Third Party Activities

Third Party Exposure10%

Geographic / Political Exposure

Construction Considerations

Use of Innovative/Complex Installations10%

Pre commissioning Observations

Marine Spread

Installation Vessels5%

Marine Vessels

Marine Procedures

Transportation Parameters

Fire Protection

Fire Fighting Provisions During Construction5%

Fire Fighting Provisions During Testing & Commissioning

As in construction rating tool a similar one was developed for operational phase of the project and listed below with all categories are explained. Industry best practice is listed here and considered to be ' Good' rating.

Lay out and Construction

Wind turbines are spaced out and designed for 100 year wave and wind criteria

Internationally accepted standards used in design and construction (API, ASTM, ANSI, TEMA, etc. The structure was built by a reputable designers and fabricators. Material certificates have been provided as per standard.

Age \leq 15years Gravity based structure considered to be good Tripods are suited for medium water depth Monopole suited for shallow water depth

Third parties

Boat landings \leq 5/week Proximity of Shipping Lane \geq 10km

Bird strike on turbine blades

Aviation threat (although minimal)

Equipment design and reliability

Internationally accepted standards used in design and construction (API, ASTM, ANSI, TEMA, etc). Flare and Blow-down Systems. Flare and Blow-down Manufacturer's warranty is given for at least 5 years and the reliability is tested and documented for each critical component.

Control Systems

All components of safety related systems (sensors, logic solvers and final control elements), as well as the voting logic of the systems, are designed to meet the specific target SILs.

Field instruments have selfdiagnosticcapability.

Good labelling on control panels of plant sections and individual equipment control. Consistentphilosophyfor labelling, use of colours for indicator lights and direction of keys and switches.

Control system provides for real time on-screen monitoring of plant conditions and alarms through operator-created schematics, alarm summary, on-screen identification of bypassed trips and trending of important process variables. Clear on-screen labelling of equipment and plant sections. Alarm management plan and effective alarm prioritisation in place.

There is no more than one alarm every ten minutes; and no more than ten alarms are displayed in the first ten minutes following a major plant upset

Management

There is a written Management of Change procedure (MOC), which applies to all units.

A MOC form, coupled with support documentation such as drawings and equipment specifications, is used to guide employees through the procedure.

Responsibilities are clearly defined.

The procedure includes a method of ranking the changes based on the potential risk. The level of risk involved with a change determines what sort

of hazard analysis methods has to be used and what level of authority is required for the change to proceed.

Management actively supports the MOC procedure.

The procedure includes a definition of a change, such as change of technology, facility, operating procedure and organizational changes. MOC reviews are conducted for changes in operating conditions, such as altering feedstock composition, increasing process unit throughput, or prolonged diversion of process flow through manual bypass valves.

Procedure comprises adequate and consistent methodology in identifying changes that should be captured by the MOC process.

Temporary changes are valid for a specific time period depending on a level of authority (e. g. shift manager 1 day, plant manager 1 week, operations manager 1 month, general manager greater period. After one year, if the change is not returned to original service, a permanent MOC should be completed.

Filing and tracking system for open/closed approved/disapproved MOC requests.

Procedure comprises adequate and consistent methodology to ensure that permanent changes are reflected in the piping and instrumentation diagrams (P&IDs).

Procedure comprises adequate and consistent methodology defining when a PSSR is required and when it is complete and the change ready for commissioning.

Safety system bypasses triggers a temporary MoC request

Extensive siting studies considering buffer zones between the plant and the

public, worst credible scenarios, exposure from adjacent plants and natural hazards are completed for construction projects.

All plants are HAZOP Studied to a schedule of at least every 5 years.

The results of risk analyses are widely known and recommendations are formally followed up.

Fir protection and detection sysystems

Detection covers all significant areas, with modern “ Intelligent” systems (VESD systems for electronic equipment) and “ Fault Tolerant” designs and the system alarms in a continuously manned location. Fire detection above critical HC pump seals and compressors. Fire detection in all control rooms and electrical equipment/cable rooms.

Fire detection in all critical control/electric equipmebnt rooms. Fire/smoke detection in all rooms and corridors.

Fire detection systems are subjected to a recorded and acceptable maintenance/testing procedure.

Incident Investigation

Procedures for doing an incident investigation including a clear definition of what is meant by incident, accident, near miss, etc.

People involved in investigation are being trained, with emphasis on root cause analysis.

Comprehensive reports are issued following the investigation with root cause analysis and recommendations to prevent recurrence. Systems are in place to follow up on the status of recommendations.

A review system (e. g. statistical analysis) is in place to detect trends and patterns among incidents to identify opportunities for elimination of commonly recurring causes.

Systems are in place to share key results of the investigation with other parts of the plant and the organization.

Near-misses (such as process excursions) are recorded and analyzed as part of the incident investigation system.

Operating Procedures & Safe Work Practices

Operating Manuals are well laid out, have a contents page. They are generally in the form of a Controlled Document and kept current. They include instructions for dealing with upsets such as loss of power, loss of air, loss of feed, furnace tube failure, etc. These are separated from the normal operating instructions. There are separate and colour coded manuals for Normal Operating Procedures and for the Emergency/Upset Operating Procedures.

All work is pre-planned and discussed at weekly/daily meetings which include Operations, Maintenance and Safety.

The Bypassing of Trips/Safety System is by formal procedure, which links with the MoC procedure.

A comprehensive Permit to Work system is in place.

There are written procedures for SIMOPS and Lifting Operations

There are written procedures for Lock Out/Tag Out for physical isolation and electrical isolation.

Comprehensive shift hand over procedures with sufficient time allowed to carry out process.

Organisation / Training / Human Element

Updated organisation chart available. Onshore. Inspection department reports to Technical Manager but not the Maintenance Manager and has Onshore backup.

All contractors must complete a safety induction course and a specific training course before working on site.

Safety performance is a key factor in the contractor selection process.

Comprehensive induction course for new employees comprises both practical and written exams with pass marks being required respectively.

All production areas have training co-ordinators appointed who provide a high quality training programme.

Key jobs have been identified and their required skills, knowledge and abilities documented.

A comprehensive database is held of all courses which have been programmed, attended and are outstanding for all personnel employed.

There are a number of active safety programmes in place such as Behaviour Based Performance

Overtime is only used for unusual situations (e. g. Regular or unplanned shutdown)

An operator will require several months training before receiving formal certification to perform the job role. Evidence of recorded refresher courses.

Operator annual turnover less than 5%.

New plant start up should have resources and training of key personnel well in advance of commissioning.

Defined educational requirements for new intakes.

Emergency Response

There is a trained Emergency Response team available at all times.

Training facilities allow all members of the team exposure to realistic fire drills at least every 3 months, if environmental regulations allow. Otherwise at least annual visits to an external specialty facility.

An Emergency Plan, which is regularly reviewed and updated, details responsibilities and initial actions to be taken. Copies of the plan are easily available to all employees. Emergency Plan includes detailed responses to specific scenarios.

There is an ECC (Emergency Control Centre) suitably equipped with basic documentation and communications.

A good proportion of the Emergency Response team is sent on intensive external courses, including special courses for team leaders.

There is an impairment procedure by which the department must authorize, or at least be notified in writing of, the impairment of any protection system.

Routine Inspection

The site has a fully established and very comprehensive Inspection Manual/Norm.

Site has implemented a comprehensive Risk Based Inspection Program for both process and structural components

Technicians have level 2 or 3 Non destructive testing (NDT) qualification for basic NDT techniques.

Welding carried out to internationally recognised standards.

Information on Inspection experience and practices regularly sought and/or exchanged with other plants.

Inspection is up to date for all critical items; and there are minimal past due items of any type.

Cathodic protection monitoring programme is in place..

Programme in-place for testing of cranes and other lifting equipment at least annually.

Positive Metals Identification (PMI) programme corrosion management program effectively controls corrosion rates prior to the loss of containment or plugging of process equipment.

Structure fatigue is being monitored.

Individual equipment records are kept up to date. All critical documentation and records are duplicated.

Mechanical Maintenance – Vibration monitoring and lube oil analysis programme.

Repeat failures are noted and corrective action taken.

Electrical Maintenance –Annual transformer oil sampling and analysis.

Instrument Maintenance –

Audits and Corrective Actions

Comprehensive process safety audit plans are implemented.

Audits are documented in a written report that contains findings and

recommendations and is shared with the workforce at the facility.

Audits are conducted by teams of plant personnel including all hierarchical levels and partially staffed with expertise from outside the plant to provide objectivity and fresh ideas.

Regular corporate audits ensure that there is a continued high level of compliance with internal procedures and external legislation.

Action plans to resolve recommendations with assigned responsibilities and follow-up systems to verify completion and track/report outstanding recommendations are in place.

All safety related procedures contain a section on audit requirements.

Routine Maintenance

Maintenance procedures are well provided and periodically reviewed.

Computerised systems are used to plan maintenance; to record all work carried out; to track spare inventories; and to provide formal reporting of overdue items.

There is no significant back-log of maintenance (max. 2 weeks normal working).

Site tour finds all operating equipment running smoothly with minimal numbers of stand-by equipment items in active repair work.

AI