Development, Design and Construction of Offshore Windfarms

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15 September 2009
Agenda

- Fluor
- Offshore Wind
- Offshore Windfarm Project Development
- Design Decisions
- Construction
- Cable Burial
- Key Interfaces
- Risks
- Lessons Learned
- Contract Structure
Fluor Overview

- One of the world’s leading publicly traded engineering, procurement, construction, maintenance, and project management companies
- #148 in the FORTUNE 500
- Over 1,000 projects annually, serving more than 600 clients in 85 different countries
- More than 41,000 employees worldwide, over 1,000 employees in the UK
- Offices in more than 25 countries on 6 continents
- Nearly 100 years of experience, 50 years in the UK
2007 Fluor Financial Performance

Revenue: $16.7 billion

New awards: $22.6 billion

Backlog: $30.2 billion

Fluor’s debt is rated at one of the higher investment grade levels:

- Long-term Secured:
  - Standard and Poors “A-”
  - Moody’s “A3”
  - Fitch “A-”

- Short-term (including CP):
  - Standard and Poors “A-2”
  - Moody’s “P-2”
  - Fitch “F2”
Offshore Wind
Market Overview

- 19 offshore wind energy projects operational representing over 1.1 GW
- Douglass Westwood offshore wind energy forecast:
  - 4.5 GW of new installed capacity in next 5 years
  - $16 billion of total capital expenditure
  - $5.2 billion of annual capital expenditure by 2012
- EWEA offshore wind energy forecast:
  - 3 to 4 GW of offshore wind energy installed by 2010
  - 10 to 15 GW of offshore wind energy installed by 2015
  - 20 to 40 GW of offshore wind energy capacity operating in EU by 2020
- Onshore wind nearing saturation in many European countries
- Europe looking to offshore wind energy to meet future renewable energy growth targets of 20% by 2020
- Large growth in USA onshore wind energy but offshore wind still in early stages of market development
European Market Capital Spend Forecast 2008 - 2012

Douglass Westwood; The World Offshore Wind Report
European Market
Factors Impacting Forecast

- German Alpha Ventus test site is fully commissioned in 2009 and delivers results for 5 MW wind turbine by 2011
- UK Round 2 projects of 500 MW or greater continue to progress and move into construction from 2009
- UK Round 3 launched in 2009 with sites allocated from 2010 onward
- Germany resolves grid connection and power pricing issues
- Sweden promotes several large-scale project due to more favorable regulatory framework
- Short term supply chain bottlenecks (turbines, vessels, skilled staff) are addressed through capacity, standardization and training
- France, Belgium and Netherlands see projects developed and completed
- Spain begins its offshore development in 2012 - 2015
UK Market

◆ Round 1
  - The Crown Estate awarded a total of 18 sites in 1999
    • Each site limited to 30 turbines and approx. 100 MW
  - To date 14 sites have received consent
  - 8 Round 1 sites operational

◆ Round 2
  - The Crown Estate awarded a total of 15 sites in 2003
    • Sites vary in size from 64MW to 1200MW
  - To date 9 sites have received consent
  - 3 sites in construction
Round 3
**Round 3 - Overview**

- **Round 3**
  - The Crown Estate’s procurement process for the development of nine zones around UK coast
  
  - The Crown Estate is targeting 25GW of capacity at an estimated TIC of GBP£80 billion by 2020
  
  - Developer to be awarded exclusive development rights
Round 3

Indicative Economic Potential for Offshore Wind

Notes:
1. This map represents The Crown Estate's current view of locations for potential zones for the development of offshore windfarms.
2. It will be subject to revision.
3. The zones do not in any way reflect the extent of BERR's SEA.
Project Development
Project Developer

◆ Greater Gabbard Offshore Winds Limited
  – A special purpose company that was owned equally by Fluor International Limited and Airtricity Holdings Limited
  – Fluor sold its equity stake to Airtricity at financial close
Project Description

- 500 MW Offshore Wind Farm Project
- Electricity output: 1.8TWh/yr
- 140 x 3.6MW Siemens wind turbines

Project Site
- Outer Thames Estuary, U.K.
- 25km offshore
- Site area = 147km²
Site Layout
Greater Gabbard Offshore Windfarm–Project Development Timeline

**Dec ‘03**
- Fluor / Airtricity JV awarded 500MW Greater Gabbard Offshore Wind Farm Project

**Dec ‘04**
- Grid Connection Offer received

**Oct ‘05**
- Consents application submitted

**Feb 2007**
- Consents received
- Siemens selected for turbines

**2004**
- Offshore Site Surveys

**Sep 2005**
- Met Mast installed

**Summer 2006**
- Offshore geotechnical surveys

**October 2007**
- FEED completed Estimate prepared

**May 2008**
- Financial Close
The Planning Process

◆ Consents Strategy
  – Section 36 for the whole project
  – Section 36 for the offshore elements and Section 90 TCPA for the onshore elements

◆ Straddling the territorial water boundary

◆ How to create flexibility?

◆ Key considerations
  – Size
  – Spacing
The Planning Process – Selected Route

1. Monopile Foundation  
2. Turbine Blade  
3. Nacelle  
4. Interarray cables  
5. Offshore substation platform  
6. Onshore substation

FLUOR®
Key Elements for Success in the Planning Process

- Consult
- Consult some more
- Listen
- Bite your tongue
- Listen
- Consult some more
Key Elements for Success in the Planning Process

- Strategy
- EIA scoping
- Understand the critical path
- Select the right consultants
- Collaboration
- Consultation
- Flexibility
- Sweat the small stuff
Key Design Decisions and Issues
Foundation Design

◆ Design inputs
  – Water depth
  – Metocean (wind / wave regime) data
  – Geotechnical data
  – Turbine loads
  – Manufacturing / fabrication considerations
  – Installation considerations

◆ Current Foundation types
  – Monopile
  – Gravity base
  – Jacket
  – Tripod
Future?

- Floating
- Multiple turbines on a single foundation
- Horizontal axis
- Combined with tidal / current turbines
Monopile considerations
- All the same or individually designed
- Tapered
- Pile top size
- Pile top, above or below surface level
- J-tubes, internal or external
- Cathodic protection
- Design / fatigue life
- Pile hammer size and capacity
- Pile handling
Monopiles
Greater Gabbard – Foundations

- Monopile
  - Individually designed
  - Internal J-tubes

- Transition Pieces
  - All the same
Greater Gabbard
– Monopile Load-out
Greater Gabbard
– Final Coating of TPs
Electrical System Design – General

- Minimising / optimising the unit cost / MWh
- Electrical system design studies
  - Load flow
  - Short circuit
  - Network harmonic / power quality
  - Voltage fluctuation
  - Power system losses / network losses
  - Earthing studies
  - Protection co-ordination
  - Cathodic protection
- Technology
  - Turbine
  - AC versus DC
Windfarm layout and interarray cable topography
- Maximising energy yield – balance between
  - Larger spacing and therefore reduced wake losses
  - Larger spacing and therefore increased cable losses and cable costs

Interarray cable
- Voltage and conductor size
- Number of turbines on a string
- Tapered systems
- Looped systems
- Redundancy

Offshore substation platforms
- Number of platforms
- Number of transformers
- Size of transformers
- HV switchgear configuration
- Redundancy
Greater Gabbard – Cable layout
Electrical System Design (Continued)

◆ Export cable
  – Single or multiple cables
  – Redundancy
  – Pinch points – Horizontal Directional Drill (HDD) / J-tube
  – Distance and terrain
  – Shore crossing
    • HDD or open cut

◆ Reactive power compensation
  – Onshore / offshore

◆ Grid Connection
Control and Communication System Design

Control System
- Integrated or stand alone
- Redundancy

Communication System
- IP, VHF, Cellphone
- Redundancy
O&M Design Issues

- HSE standards
- Onshore vs offshore based
  - Workboats
  - “Hotel” vessel
  - “Hotel” platform
- Port base location
- Access method
  - Boat
  - Helicopter
- Sparing philosophy
- Lifting plans for major components
Key Construction Decisions and Issues
Construction – The Basics

- To date offshore wind farms are adopting ("Lego-type") onshore construction methods
- The actual offshore construction works must be kept to a minimum and as simple as possible
- Extensive and early installation engineering and planning is vital
- Maximise the assembly and commissioning of turbines onshore
- Experience and capability of the marine subcontractors is critical
  - A partnering approach should be considered
- Maximising the utilisation of the major construction plant is critical to driving down the cost
- The ‘marine and project logistics’ is complex and a robust process must be developed

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Construction Considerations

- **Foundations**
  - Type (monopile, gravity, jacket)
  - Soil conditions & water depths

- **Towers & Turbines**
  - Pre-assembly of nacelle/blades
  - Pre-cabling of towers

- **Cables – Export & Inter-array**
  - Easy for jack-ups to damage
  - Connections to foundations and offshore transformer platform
  - Export cable landfall and connection to onshore substation

- **Offshore Transformer Platform**
  - Modular or custom
  - Size & weight

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Nacelle Installation
Construction Challenges

- **Installation vessels**
  - Tight supply in Europe

- **Staging and O&M Ports**
  - Substantial up-front planning required

- **Supply Chain Constraints**
  - Lead times for major equipment & material continue to increase
  - Commodity costs

- **Logistical Planning**
  - Stock piling at staging port
  - Work around weather windows

- **Weather Impacts**
  - Wind, wave, current limitations
  - Access to foundation and nacelle
  - Safety


Logistical Challenges

- **Logistics & Sequencing**
  - Equipment and material deliveries
  - Number and types of vessels
  - Batch installations

- **Staging ports**
  - Proximity to offshore site
  - Space needs - stock piles, pre-commissioning
  - Vessel traffic & loading areas (quay space)

- **Coordination with Suppliers**
  - Design, manufacturing, delivery, installation
  - WTG Installation and commissioning support

- **Grid Connection**
  - Electrical infrastructure completion
  - WTG commissioning

- **Disruption Contingencies**
  - Adverse weather
  - Late deliveries
  - Vessel failures
There are a number of different types of vessels that can be used to construct offshore wind farms:

- Flat bottom barges, shear leg cranes and land based cranes
- Dynamically positioned vessels
- Semi-submersible installation
- Jack-up installation
- Hybrid vessels
Greater Gabbard

Monopile size and weight (up to 700 metric tonnes and 6.5m in diameter) is much larger than previous installations

Needed to look outside the normal vessels associated with the Offshore Wind Industry to date and consider heavy lift vessels
Greater Gabbard

140 WTG & Tower installations

Typical installation cycle time is 4 days for two WTGs & Towers (including load out and transit time to and from the staging port)
Greater Gabbard has a “mother” OTP, which uses a jacket foundation due to large size and weight of OTP and relatively deep water.

Monopiles can be used for smaller OTPs depending on weight and water depth.

OTP design (modular vs. custom) will also impact foundation design and installation vessel selection.

Typical Jacket Foundation
The 50km 132 kV export cables are approximately 4,500 tonnes each.

Typical installation cycle time is 42 days for one 50 km cable (including collection from cable supplier).

The 33kV inter array cables are smaller in dimension than the export cable and allow the use of smaller installation vessels.

Typical installation cycle time is 5 days for four cables (including load out and transit time to and from the staging port).
Cable Burial and Entry
Cable Issues

- Identification of hazards to cables
- Site investigation to identify seabed properties (geophysical survey, vibrocore sampling, cone penetrometer tests, boreholes)
- Development of burial protection indices
- Scour protection
- Cable route selection
- Cable transport
- Vessel and equipment selection
Exposed Cable and Cable Entry

Seabed

Cable

Underground ~ 27 m Exposed ~ 3 m Span

Monopile

Cable Entry

Inside

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Functional Requirements

◆ Cable protection against
  – Environment – waves, current, storm
  – Dropped Objects – anchors, construction, maintenance
  – Scour – undermining stability
  – Fishing – trawling, dredging

◆ Monopile protection against
  – Water ingress into MP – internal corrosion
  – Scour – pipe instability
Typical Solution – Monopile J Tube

- Monopile
- Bend restrictor and seal
- Rock Dump or Mattresses
- Scour
- Seabed
- Cable
- Underground
- Exposed
- Span
- Inside
- Cable Entry

~ 27 m
~ 3 m

Typical Solution – Monopile J Tube
Key Interfaces
The design of the foundation is an iterative process with the WTG supplier. Key issues include:
- Establishment of load cases
- Identification of control cases (e.g., shallowest, deepest, weakest soils)

The physical interface
- WTG tower / transition piece flange design
- Electrical interface
- Control systems interface
Electrical System Design

- Critical electrical system design interface is between the WTG and Balance of Plant
  - Completion of electrical system studies
- Client’s operational and safety requirements
- Grid code compliance
  - Modelling and testing
- Electrical system studies
- WTG and overall windfarm commissioning and system testing requirements
Control Systems

- Interface between WTG SCADA, BOP SCADA, Grid system operator and Owner’s systems
- Energy management systems and forecasting
- Regulatory requirements and standards
- International and local standard requirements
- Standard control systems protocols
Other Interfaces

- Communication links
  - VHF / radio / cell phone and or land connections

- Physical connection interface between windfarm’s onshore substation and the grid
  - Quality
  - Safety
  - Operations
  - Commercial arrangements

- Submarine / land cable interface

- Cable interfaces with WTG and offshore substation platform

- Offshore substation platform / foundation interface
Risks
Risk Management  
– Pre-construction Risks

- Securing landowner permissions
- Grid availability  
  - Onshore reinforcement
- Component lead times
  - Wind turbines
  - HV electrical equipment (cables, transformers)
- Availability of suitable offshore construction vessels
- Reservation payments
  - Wind turbines
  - Vessels
  - HV electrical equipment
- Material prices
  - Steel
  - Copper
- Project finance
  - Availability of debt / equity
  - Availability of insurance
Risk Management
– Construction Risks

- Weather
- Marine logistics / supply chain management
- Ground conditions
- Availability of key resources
  - Personnel
  - Marine equipment
- Cable burial
Risk Management – O&M Risks

- Weather
- Accessibility
- Availability of key resources
  - Personnel
  - Marine equipment
Risk Management – Interface Risk

- WTG / Tower / Transition Piece / Monopile Foundation interfaces
- Offshore Substation Platform / Foundation interfaces
- Electrical System Design through Commissioning interfaces
- Control Systems Design, Compliance and Owner/Operator interfaces
- HV / MV Submarine and Onshore Cable interfaces
- Communication interfaces
Lessons Learned from UK Offshore Windfarms
Lessons Learned
– Surveys

- Geotechnical surveys
  - Insufficient data gathered
  - Not in the right place

- Geophysical surveys
  - UXO
  - Marine archaeology

- Metocean surveys
  - Insufficient data gathered
  - Wave regime
Lessons Learned – Engineering

- Critical to have experienced design and installation engineering capability
- A robust engineering plan is required
- Construction and installation engineering should be completed in parallel with design engineering
- Interface management
Lessons Learned – Cables

- Cables have been the major issue for offshore windfarms
- Typical difficulties:
  - Access difficulties due to unexpectedly severe weather climate
  - Harder or softer ground being encountered impeding burial machinery
  - Unexpected topography, e.g., slopes, holes
  - Poor definition of environmental risks leading to tight permitting windows
  - Poor appreciation of the wave/tidal environment leading to tight operational windows
  - Poor understanding of marine environment leading to excessive weather delays
Lessons Learned
– Cables

◆ Root causes:
  – Unrealistic permit conditions being passed onto contractors to implement
  – Lack of consultation with cable manufacturers / marine contractors regarding the practicalities of installation
  – Poor understanding of weather and marine environment
  – Lack of quality in cable route survey definition and data interpretation for the cable route
  – Developers have accepted consent conditions that are unrealistic or not practical
  – Poor understanding of impacts on construction
Lessons Learned – Marine Access / Construction

- Poor understanding of site metocean characteristics
- Poor understanding of operational limitations of all construction / support vessels
- Late identification of onshore port requirements
  - Sufficient space / load bearing capability
  - Onshore equipment
  - Loading/unloading capability
  - Vessel restrictions
- Levels of redundancy in equipment, eg hammers, drilling
- Management of supply chain / logistics
- Late involvement of marine contractors
Lessons Learned – Risk Allocation

- Weather risk
- Geotechnical risk
- Interface risk
- Consent risk
  - Noise
  - Archaeology
  - UXO
  - Marine mammals
Lessons Learned – Commissioning

- Too much commissioning offshore
- Poor understanding of access constraints
  - Little focus on type of vessel to be used
- Personnel transfer methods
Contract Structures
Offshore Windfarm Contract Structures

◆ Multi-contract
  – Pros
    • Potentially lower cost
    • Contingency held by owner
  – Cons
    • Higher risk for owner
    • Multiple critical interfaces to manage (small critical subcontracts can have significant impacts)
    • Requires large owner management team

◆ Full EPC wrap contract
  – Pros
    • Single point of contact – lower risk to client
    • Small owner management team
  – Cons
    • Potentially higher cost
Greater Gabbard Offshore Winds Limited (GGOWL) has entered into 3 main contracts:

- Siemens Wind A/S
  - Supply of 140 x 3.6MW offshore wind turbines
  - 5 year service and warranty agreement
- Fluor Limited
  - EPC LSTK for Balance of Plant including installation of turbines
- National Grid Electricity Transmission plc
  - Connection to the National Grid
Fluor Scope of Work

◆ Fluor Scope of Work
  – Installation of 140 offshore wind turbines (supply by Client)
  – Supply and installation of 140 foundations and transition pieces (approx 120,000 tonnes steel)
  – Supply and installation of high-voltage (132kV) subsea export cable (approx 180 km)
  – Supply and installation of medium-voltage (33kV) inter-array cable (approx 173 km)
  – Supply and installation of onshore substation
  – Supply and installation of 2 offshore transformer platforms (approx 2,500 tonnes each)
  – Supply and installation of 1 met mast
  – Supply and installation of SCADA control system

◆ Fluor Scope of Services
  – EPC LSTK
Early Supplier Collaboration

- Lead times for key equipment are long
  - Turbines: 2 years
  - High Voltage transformers: 18 months
  - High Voltage cable: 18 months
  - Installation vessels: 18 months or more

- Early supplier collaboration is necessary and drives benefits
  - Unique expertise and product knowledge
  - Drives efficiencies in design
  - Increases innovation
  - Reduces engineering effort and rework
  - Improves quality
  - Optimises life cycle costs

- Commitments are required
The ability to influence the cost of a project is greatest at the beginning of a project; bringing strategic suppliers in early is essential to success.
Questions
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