Overview of Phases

Design Verification

- Site Assessment – Complete
- Design Basis – Complete
- Load Simulation – in Process
- Detailed Design – in Process

Manufacturing Verification

- Jacket Fabrication – in process
- Wind Turbine Manufacturing – in process
Five blade sets, LM Windpower, Denmark – completed March 2014
Castings – Faw Foundry, China, Feb 2015

<table>
<thead>
<tr>
<th>Diameter</th>
<th>width</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 m</td>
<td>4.5 m</td>
<td>48.9 T</td>
</tr>
</tbody>
</table>
Deck Legs – Gulf Island Marine, Houma, LA
Manufacturing Surveillance - Substructure

Jacket Flanges – Euskal Forging, Sistao Spain
Manufacturing Surveillance - Substructure

TP– EEW, Rostock, Germany
Racetrack connection of Deck – Gulf Island Marine, Houma, LA
Manufacturing Surveillance - Substructure
Manufacturing Surveillance - Substructure

Jacket Piles – EEW, Korea

UT check of longitudinal weld

straightness

bevel
Site Assessment

Inputs

- Meteorological Reports
- Metocean Reports
- Geophysical Survey
- Geotechnical Survey
- Geotechnical Interpretation Reports
- Applicable laws, lease and permits
- Interconnection requirements
Analysis

- Annual wind characteristics
- Extreme event analysis
- Directional Joint probability analysis
- Geotechnical and Geophysical data collection
- Soil-Pile interaction: pile capacity, P-y, T-z, Q-z curves

ABS Deliverables

- ABS BIWF Report - Site Assessment Verification 2014-11-26-r0
Geotechnical Data Verification

P-Y Curves (Lateral)

T-Z Curves (Axial)

End Bearing

BIWF CVA Status - presented to CRMC 2015-Mar-10
Inputs:
Designers’ interpretation of design inputs based on site assessment

Preliminary Design

Substructure – Keystone
- Substructure Design Basis
- Preliminary Design Report
- Preliminary Design Drawings

Wind Turbine – Alstom
- Tower Structure Design Basis
- Tower Internals Design Basis
- Wind Conditions
- Turbine General Description
Design Basis

BIWF CVA Status - presented to CRMC 2015-Mar-10
Analysis

Review of regulations and standards applied
Review of concept design
Reduction of wind and ocean data
  Wind bins and annual probability distribution
  Wind, wave, and current direction distribution
  Extreme event modeling

ABS Deliverables

ABS BIWF Report - Design Basis Review - 2014-12-08-r0
Design Basis
Verification of Integrated Model
- Review of Design Load Case definitions
- Review of integrated load simulation methods
- Review and spot check of integrated load simulation results
- Check of site specific results against type-certification load envelope

Design evaluation of wind turbine
- Site specific loads
- Environmental conditions
- Local regulations
- Any changes from the type certified model
- Electrical and mechanical hazards to personnel
- Corrosion protection
Design evaluation of sub-structure

- Review of detailed strength calculation methods and results
- Review of manufacturing drawings, specifications, and instructions (compared to calculation assumptions and applicable standards)
- Review of O&M procedures (effect on structural integrity and design life)
- Finite element analysis
- Corrosion protection
Overview

Turbine and structure are modeled in Bladed and SACS with different levels of detail.

Time domain simulations according to the DLC list:
- 1758 ULS simulations
- 1272 FLS simulations

Force time histories at the tower base flange are output from Bladed to SACS to apply turbine and tower aerodynamic and operational loads to the substructure.

Sea surface profiles are output from Bladed to SACS for identical wave definition.
Load Simulation

Bladed (turbine + tower design)

Mean Wind + Turbulence

Wave train

Interface Loads

BIWF CVA Status - presented to CRMC 2015-Mar-10
Bladed

- Integrated turbine, tower, and jacket structure modeled as beam elements
- 3-d wind field
- Blade aerodynamic characteristics
- Combined wind and wave forces
- Turbine operational behavior modeled in detail
- Soil-structure interaction is modeled as a 3-d stiffness matrix
- Substructure complex members (grouted members, racetrack) are modeled with equivalent mass, stiffness, moments of inertia
- Full capture of combined environmental, operational, and dynamic loading
- Bladed results are used for tower site specific design
SACS

Integrated tower and jacket structure modeled as beam elements, RNA included as a point mass for natural frequency analysis
Mode shapes include tower and RNA dynamics
Wave definition identical to Bladed
Piles and grouted members are included in structural model
Soil-pile interaction modeled with P-y, T-z, and Q-z curves applied along the pile
Wind, operational, and dynamic loading from RNA and tower is input from Bladed at the tower bottom flange
Hydrodynamic and dynamic loading on the substructure
Post processing for ULS and FLS of substructure members and joints
Load Simulation

Inputs

Substructure – Keystone

DLC list
Modeling and Analysis Methodology
Data exchange with Turbine designer
Model Calibration
Natural Frequency Analysis to determine driving location
SACS Input files
  Structure, soil, wind, wave, and current definition, marine growth
SACS Output files
Load Reports
Inputs

**Wind Turbine – Alstom**

- DLC list
- Modeling and Analysis Methodology
- Data exchange with Substructure designer
- Model Calibration
- Bladed Input files
  - Structure, soil stiffness matrix, 3-d wind field,
  - wave and current definition, marine growth
- Bladed time series
  - sea surface profile, interface loads
- Load Reports
Analysis

DLC list – consistency with site assessment data

Modeling and Analysis Methodology
- Best practice
- Best available tools
- Simplification – acceptable when results are conservative

Detailed comparison of SACS and Bladed models
- Structural properties
- Wind, wave, and current definition
- Dynamic response
- Loop 1 – errors found – soil coordinate systems, export SACS to Bladed
- Corrected in Loop 2

Results
- Compare ULS and FLS results from Loop 2

ABS Deliverables
- ABS BIWF - Calibration Verification Report
Bladed
Use Alstom .prj file with encrypted blade
Use Alstom encrypted turbine and pitch controller .dll
RNA and controller must be consistent with type certified design
Tower is site specific design by Alstom
Substructure is site specific design by Keystone
Design Phase
ABS BIWF Report - Site Assessment Verification 2014-11-26-r0
ABS BIWF Report - Design Basis Review - 2014-12-08-r0
ABS BIWF Report – Calibration Verification 2014-02-23-r0
ABS BIWF Report – Load Simulation - Pending

Manufacturing Phase
ABS BIWF Report – Blade Manufacuring Verification
ABS BIWF Report – Jacket Flange Manufacuring Verification
ABS BIWF Report – TP Manufacuring Verification
ABS BIWF Report – Jacket Pile Manufacuring Verification - Pending
ABS BIWF Report – Casting Manufacuring Verification - Pending
Next Steps

March-April
Complete Verification of Loads, Detailed Design Facilities Design Report
Fabrication and Installation Report
Continue Manufacturing Verification of WTG and Substructure

June
Loadout and Transportation of Jacket
Continue Manufacturing Verification of WTG

August-September
Installation of Jacket
Continue Manufacturing Verification of WTG...

Summer 2016
Installation and Commissioning of WTG