SACS Offshore Analysis & Design Software
July 2013

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SACS Offshore Analysis & Design

SACS Overview

What’s New In SACS

SACS In Detail
- Jacket & Topsides Design
- Jacket & Topsides Installation
- Wind Turbine Structures
- Offshore Vessels
- Construction

SACS Products

Future Developments
SACS Overview
Some Bentley Offshore Users:
Offshore Structures

SACS has applications for all types of offshore structures:

- **Topsides & Jacket**
  - Fixed Platform
  - Compliant Tower

- **Topsides Only**
  - TLP’s
  - Semi-submersibles
  - Spars
  - FPSO’s

- **Vessels**
  - FPSO’s
  - Barge transportation
  - Heavy Lift Ships
  - Drill Ships
SACS – Principal Applications

- Fixed Platforms (Jackets)
- Topsides of Fixed & Floating Platforms
- Wind Turbine Support Structures
- Offshore Vessel Cargos & Topsides
Applications for all project phases

Design → Construction → Installation → Decommissioning
What’s New in SACS (v5.5 & v5.6)
What’s New in SACS v5.6 (Sep 2013)

<table>
<thead>
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<th>SACS V8i SELECT Series 3 (v.5.6)</th>
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<td>Precede : Ring Stiffener Meshing</td>
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<td>Precede : Automatic Topsides Deck Meshing</td>
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<td>PSI/Collapse/Pile3D : Soil Liquefaction Effects</td>
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<td>SACS Reports : New Interactive Reporting Functionality</td>
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<td>Trust Licensing</td>
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Hull Mesher

• Objective is to provide improved modeling of stiffened plate structures (complement to Precede)

• Ability to model barges, parts of FPSO, decks etc.

• Based on acquired FormSys Multiframe technology

• Will become another SACS interactive application
  – Part of SACS Marine Enterprise

• End goal is to integrate into Precede

• Side benefits
  – New re-usable class based on new Datagen code for reading and writing SACS models
Hull Mesher – Key Functions

- Sketching and interactive meshing of arbitrary plate panels
- Associativity between panels and stiffeners
- Automatic generation of attached stiffeners, plates and face plates
Hull Mesher Examples
Automatic Joint Meshing
Non – Tubular Joint Meshing
Tubular Member Meshing
Precede – Ring Stiffened Tubes
Precede - Automatic topsides deck meshing

Automatically mesh selected plate and surrounding members
Post Processing

EUROCODE 3

European EC3: 2005 design code update

EC3 National Annexes: UK, Norwegian, Malaysian, Singapore, German

Sections Available: Wide Flange, Plate Girder, Box Section, Rectangular Tube, Double Web Plate Girder, Boxed Plate Girder, Unsymmetrical Plate Girder
Member Code Checks

NORSOK 2013 UPDATE

NORSOK STANDARD
Precede/Postvue: Consolidation of viewers
Precede/Postvue: Consolidation of viewers
Wind Turbine Analysis

Automated SACS Uncoupled Wind Turbine Process – Strength Analysis

- Control File
  - sacs.in
- Partial Seastate Input File
- PSI Input File
- Joint Can Input File

SACS Multi Core Analysis

DB

Strength Results
Wind Turbine Analysis

SACS-GH Bladed Interface - Strength

Control File
sacs.in

POST Input File

Joint Can Input File

GH Bladed Results

SACS Multi Core Analysis

DB

Strength Results
Wind Turbine Analysis

Automated SACS Uncoupled Wind Turbine Process - Strength
Wave Response / Dynamic Response – API / FROY Spectrum

Spectral Wind Fatigue
- Generalized Force Spectrum: API/FROY
- Wind Speed Distribution: Weibull Distribution

Extreme Wind Analysis
- Generalized Force Spectrum: API/FROY
- Creates results containing the DAF
- Combine results with static analysis for code checking
PSI/Collapse/Pile3D : Soil Liquefaction Effects

Factor soil strata if factor of safety is less than one

Average Brandenberg [3]
SACS Reports

• SQLite Database to store all results from Solve & Post
  - Results stored from all analysis types (inplace, leadout…etc.)

• Report Engine
  - Extracts data from the database and generates reports in the various formats

• Report Designer
  - Allows the user to design reports/ use existing templates/design new templates (all in XML format) which can then be pulled into the main XML report or sent straight to the report engine. For example, the user can have templates for joint displacements, reactions, member internal loads…etc. These can then be included in the main XML report description or sent directly to the report generator.
  - Stand alone external application
SACS Reports

• Report Rendering Control
  - Allows the user to view reports in various applications such as the SACS Executive, Postvue, Precede—in word/pdf format. Reports will be constant over all applications

• Results from database can be accessed by Postvue for graphical presentation
  - Users can graphically access results from all stored analysis types.

• Results from large analysis (e.g. wind turbine analysis)
  - Since results are not stored in memory, handling and filtering large datasets will not be an issue.
SACS Reports

- Incremental Release of Features
- Release 5.6
SACS - ProjectWise Integration

- Model File to be Exposed in Precede and Datagen
SACS Licensing

- Pooled and Trust Licensing – same as all other non-structural Bentley Products.
  
  - Provide ability to maximize license utilization and minimize the burden of administration
  
  - with trust licensing, disconnected users will only need to connect to the Bentley server once every 30 days
What’s New in SACS v5.5 (Dec 2012)

<table>
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<th>Feature</th>
<th>Description</th>
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<tr>
<td>SACS V8i SELECT Series 2 (v.05.05.00.05)</td>
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<td>Marine : Stability Analysis</td>
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<td>Marine : Motion Prediction</td>
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<td>Interoperability : Compatible with ISM 3.0</td>
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<td>Post- Processing : Canadian Design Code CSA S16:2009/AISC mixed code post processing</td>
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<td>Post- Processing : AISC LRFD/CSA S16/EC 3 – user defined plastic modulus</td>
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<tr>
<td>SACS Executive : Integration of FAST interface into SACS Executive</td>
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<td>SACS Executive : Fully automated SACS uncoupled wind turbine analysis</td>
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<td>SACS Executive : Default license setup dialog box.</td>
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<td>SACS Executive : Multi-Core feature now available with Offshore Structure Enterprise</td>
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<td>SEASTATE : DNV Wake Encounter Method</td>
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<tr>
<td>Precede : Ribbon Bars added for a newer look and feel</td>
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<tr>
<td>Precede : Tubular Joint Meshing</td>
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Marine:

• New capabilities
  – Hull modeling
  – Motions prediction
    • Import of SACS model as cargo or topsides
    • Integration with TOW for inertial loads
  – Intact and damage stability analysis
  – Longitudinal strength analysis

• Suitable for
  – Installation barges
  – FPSOs
  – Drillships
  – Heavy lift vessels
  – OSV cargo calcs
Interoperability ISM v3.0

- SACS links with ProSteel for steel detailing of topsides
- Uses Bentley’s ISM (Integrated Structural Modeling)
  - Also allows model to be reviewed in free Structural Synchronizer viewer
  - Free iPad model viewer is also available on iTunes
  - www.bentley.com/iware
Post Processing

EUROCODE 3 & Mixed code checking

European EC3: 2005 design code update

EC3 National Annexes: UK, Norwegian, Malaysian, Singapore, German

Sections Available: Wide Flange, Plate Girder, Box Section, Rectangular Tube, Double Web Plate Girder, Boxed Plate Girder
Wind Turbine Analysis
SACS – Uncoupled Analysis

Fully automated with multi-core analysis
New Ribbon Interface

• Executive

• Precede
Jacket & Topsides Design
In-Place Analysis

Static Analysis with PSI
Code Check Design
Fatigue Analysis
Earthquake Analysis
Safety Case Design
Pile-Soil Interaction (PSI) Analysis

Module – Pipe Structure Design

- API P-Y / T-Z Soil
- API Adhesion Soil
- User Defined P-Y / T –Z Soil
- User Defined Adhesion Soil
Wave Load Theories

Module – Offshore Structure Enterprise

Airy’s Linear
Cnoidal
Solitary Wave
Stokes 5th Order
Stream Function
Wind Load Design for Topsides

Module – Offshore Structure Advanced
Earthquake Analysis

Module – Fatigue Enterprise

• Spectral Loading
  • API response spectra built in
  • User defined spectra
  • Modal combination SRSS or CQC
  • Generate Equivalent Static Loads

• Time History Loading
  • Variable Time step Integration
  • Nonlinear fluid damping
  • Linear, quadratic or cubic interpolation between time history input values
Fatigue Analysis

Module – Fatigue Enterprise

- Spectral
  - Pierson Moiskowitz
  - Ochi-Hubble
  - JONSWAP
  - User Defined

- Time History
- Deterministic

S-N : API, HSE, AWS, NORSOK, ISO, USER DEFINED

SCF: Efthymiou, Kwang and Wordsworth, Smedly and Fisher, Marshal, DNV
Interactive Fatigue Analysis

Module – Interactive Fatigue

• Change fatigue parameters on-the-fly (SCF, S-N)
• Generate Reports and Plots Interactively
• Auto redesign
Spectral Wind Fatigue/Extreme Wind Analysis

Module – Fatigue Enterprise

Spectral Wind Fatigue

• Generalized Force Spectrum : Harris Spectrum
• Wind Speed Distribution : Weibull Distribution

Extreme Wind Analysis

• Generalized Force Spectrum : Harris Spectrum
• Combine results with static analysis for code checking
Member Code Checks

Module - POST:

NORSOK STANDARD

EC/3
Detailed Joint Design

Module - JOINT CAN:

- ISO
- NORSOK STANDARD
- cisc icca
- NPD
Joint Modeling

Module – Joint MESHER:

• 3D Mesh of tubular joint in seconds
• Automatically identify chord and brace members
• Seamless integration into SACS model
• User controlled mesh density
Non-Linear Dynamic Ship Impact Analysis

Module - DYNAMIC RESPONSE / COLLAPSE:
Ship Impact
Non-Linear Dropped Object Analysis

DYNAMIC RESPONSE / COLLAPSE:
Minimize accidental explosions.
Jacket & Topsides Installation
Fabrication

Module – Offshore Structure

- Bent Roll Up - Jacket manufactured in portions which are then rolled over using slings and joined together.

- Structure subject to sling forces
Loadout Analysis

Module – Offshore Structure

- Analyze Jacket for loss of support
- Static Analysis with Non-Linear Gap Elements
Transportation Analysis

Module – Offshore Structure Enterprise

Tow Analysis
Static Analysis with Non Linear Gap Elements
Sea fastener Design (FEMGV)
Lift Analysis

Module – Offshore Structure
FEM GV

Design Structure for Lift Forces

Design Lift Pad Eyes (FEMGV)
Launch Time History Analysis

Module – Offshore Structure Enterprise + Marine

Jacket & Barge Motions

Hydrodynamic Forces

User defined drag areas
Flotation and Upending Analysis

Module – Offshore Structure Enterprise + Marine (Enterprise) + FEM GV

Stability and Upending Analysis

Dual Hook Capabilities

Buoyancy Tanks, Valves, User Defined Buoyancy
Deck Installation – Lift Analysis

Module – Offshore Structure Enterprise
Offshore Wind Turbine Foundation Concepts

Monopile 0<30m

Jacket 30m<60m

Floating 60m+

SACS 35+ years experience in designing offshore jacket structures
SACS - Life Cycle Applications for Analysis and Design of Wind Turbine Platforms

FABRICATION

INSTALLATION

INPLACE CONDITION
Offshore Wind Turbines

Typical offshore wind turbine consists of a turbine and tower which are attached to a partially submerged substructure (jacket).

The substructure is fastened to the ocean floor using foundation piles.
VESTAS V164 7.0MW: 164 m diameter, 80 meter blade length, tip height = 187m, hub height = 105m
Wind Turbine Fatigue Analysis

Loading on Structure

Dynamic Response of Structure

Wind Spectrum

Von Karman Harris Kaimal User Defined

Wave Spectrum

Pierson-Moskowitz JONSWAP Ochi-Hubble User Defined
Wind Turbine Fatigue Analysis

Aerodynamic and Mechanical Turbine Forces

Aero Elastic Programs

**GH Bladed**
Garrad Hassan, UK

**SACS Version 5.4**

**FAST**
National Renewable Energy Laboratory (NREL), USA
[www.nrel.gov](http://www.nrel.gov)

**SACS Version 5.5**

**Flex 5**
Stig Øye at Department of Fluid Mechanics at The Technical University of Denmark.
Fatigue Analysis

FATIGUE:

S-N : API, HSE, AWS, NORSOK, ISO, USER DEFINED

SCF: Efthymiou, Kwang and Wordsworth, Smedley and Fischer, Marshal, DNV
Wind Turbine Fatigue Analysis

• Typical Simulation:

  For each wave in scatter diagram, use six ten minute random seastate profiles

  Analyze structure every 0.05 seconds

  Total number of load cases to analyze per wave = 6 x 600 /0.05 = 72000
SACS Multi-Core Analysis

- Hundreds of time history load cases, SACS Executive runs each case on a different core
Multi-core Performance

Total time to run 8 wave response analyses (min)

Number of Cores

(* hyper-threaded)

Improvement

2 cores = 34%
4 cores = 46%
8 cores = 52%

Computer
Windows 7 64bit
Intel I7 1.73GHz
8 GB RAM
Wind Turbine Project

London Array Offshore Windfarm
175 Foundations

Depth vs. Loading

Max. extreme 50 year water depth

<table>
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<th>Load Group</th>
<th>Max extr. 50-yr WD</th>
<th>Representative locations</th>
<th>Selected location representative for</th>
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<tr>
<td>I</td>
<td>0 - 10.5</td>
<td>NG14</td>
<td>F</td>
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<tr>
<td>II</td>
<td>10.5 - 15.0</td>
<td>NJ16, NH14</td>
<td>E</td>
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<td>III</td>
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<td>NM17, (NF01)</td>
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<td>25.6 - 29.6</td>
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<td>B</td>
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<td>29.6 - 32.2</td>
<td>NF10</td>
<td>A</td>
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<td>VII</td>
<td>max scour</td>
<td>NG13</td>
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</table>
Wind Turbine Project

The Joint Venture Contractor of Aarsleff and Bilfinger Berger (ABJV) has been selected as the contractor for the construction of the London Array Offshore Wind Farm on the East Coast of the UK. The designer is COWI-IMS Joint Venture.

- 175 Steel Monopile Foundations
- 630 MW of Power
- Waterdepth up to 25 m
- Monopiles w/ 4.7 - 5.7m diameters
- Penetration up to 40m below mudline

# 7
24 Feb 2010
Stig Balduin Andersen
Structural Aspects of offshore Wind Turbine Foundations
Wind Turbine Project

Structural Model

- Structure is modelled with beam elements
- Soil is modelled with p-y curves
- Calculation with offshore program SACS

FEM of soil-structure interaction

Tower
Transition Piece
Grouted Connection
Monopile

# 8
24 feb 2010
Stig Balduin Andersen
Structural Aspects of offshore Wind Turbine Foundations
SACS Offshore Vessel Capabilities

• New capability following Formsys acquisition in Nov 2011
• Introduced Q4 2012 in v5.5
• Analysis of topsides structure
  – FPSOs, drill ships
• Installation/Motions studies
  – Barges, heavy lift ships, OSVs
• Stability Studies
  – Intact, damage, strength for any vessel
SACS Marine Enterprise v5.5

• New SACS Marine Enterprise comprises –

• Existing Tow and Floatation modules

• 3 New Modules
  – SACS Hull Modeler
    • Hull Modeling
  – SACS Stability
    • Intact and Damaged stability
  – SACS Motions
    • Motions Prediction
SACS Hull Modeler

• Modeling of any offshore vessel
  – FPSO, drill ship, barge, heavy lift, OSV

• NURB surface modeling compatible with Microstation and Rhino

• Many import options for existing designs

• Existing SACS barge library
SACS Hull Modeler
SACS Stability

- Intact and damaged stability of any type of vessel
- Integrated compartmentation and weight editors
- Ideal for FPSOs, drill ships and barges
- Comprehensive support for stability criteria
SACS Stability

- Intact and damage stability of any vessel
SACS Motions

- Prediction of vessel motions (RAOs)
  - Strip Theory or
  - Panel Methods
- Suitable for FPSOs, drill ships, barges, OSVs
- Saves SACS Tow file for inertial load analysis
SACS Motions

• Motions prediction of vessels – RAO’s and accelerations
Detailing and Construction

- SACS links with ProSteel for steel detailing of topsides
- Uses Bentley’s ISM (Integrated Structural Modeling)
  - Also allows model viewing on iPad and in free Structural Synchronizer viewer.
- Bentley ConstructSim can be used for time based construction simulation
## Common SACS Analysis Scenarios

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<td>Topsides Analysis</td>
<td>Offshore Structures Advanced</td>
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<td>Dynamic Wave Fatigue Analysis</td>
<td>Offshore Structure Enterprise, Pile Structure Design, Fatigue Advanced - Wave Response</td>
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<td>Static Fatigue Analysis</td>
<td>Offshore Structure Enterprise, Fatigue</td>
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<td>Seismic Analysis</td>
<td>Offshore Structure Enterprise, Pile Structure Design, Fatigue Advanced - Dynamic Response</td>
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<td>Seismic - Ductility Analysis</td>
<td>Offshore Structure Enterprise, Pile Structure Design, Fatigue Advanced - Dynamic Response, Collapse</td>
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<td>Offshore Structure Enterprise, Fatigue Advanced - Dynamic Response</td>
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<td>Extreme Wind Analysis</td>
<td>Offshore Structure Enterprise, Fatigue Advanced - Dynamic Response</td>
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<tr>
<td>Accidental Loading - Static</td>
<td>Offshore Structure Enterprise, Pile Structure Design, Collapse</td>
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<td>Flotation Analysis</td>
<td>Offshore Structure Enterprise, Marine</td>
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<td>Launch Analysis</td>
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<td>Loadout Analysis</td>
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<td>Tow Analysis</td>
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<tr>
<td>Tow Fatigue Analysis</td>
<td>Offshore Structure Enterprise, Marine Enterprise, Fatigue</td>
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<tr>
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<td>Offshore Structure Enterprise, Dynamic Fatigue Enterprise, Collapse, Pile Structure Design</td>
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<th>COMBINE</th>
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<th>Super Element</th>
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<th>Top-Sides Loading</th>
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<td>Pile Structure Design</td>
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<td>Marine Enterprise (new Q4 2012)</td>
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Future Developments
Future Developments

• During 2014

• Further integration of PostVue with Precede

• New Collapse solver

• Enhanced design code support
  – Additional EC3 sections, Plate panel buckling, AISC 2010

• Extend our marine capabilities adding mooring, time domain motions and more tightly coupled motions and structural analysis
Thank you -

Phil Christensen
Director of Product Development – Offshore
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