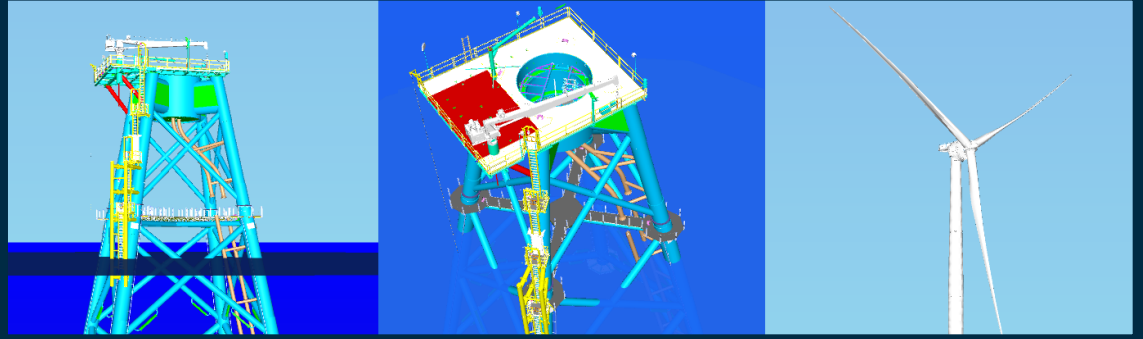


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Advancing Infrastructure



## Project Summary

### Organization:

Keystone Engineering Inc.

### Solution:

Offshore

### Location:

Block Island, Rhode Island,  
United States

### Project Objective:

- Design jacket-type substructures for five, 6-megawatt wind turbine generators for the USD 290 million Block Island Wind Farm.
- Optimize design to mitigate risk, minimize steel weight, and reduce fabrication and installation costs.

### Products used:

SACS

## Fast Facts

- The interoperability of SACS enabled collaboration between two engineering firms using different software and ensured accurate modeling throughout the project.
- Design began in Q1 2014, fabrication was performed in Q4 2014, and jacket installation was completed in Q3 2015. Turbine installation will be completed in Q3 2016.
- The offshore wind farm is projected to reduce energy costs for Block Island residents by 40 percent, as well as reduce harmful emissions.

## ROI

- Using Bentley SACS to perform multiple simulations and design iterations simultaneously, Keystone shortened the design cycle by 50 percent compared to European offshore wind projects.
- As a result of the iterative design process, the 350-ton deck and 400-ton jacket are 15 percent lighter than they would have been without design optimization in SACS.
- Optimizing the amount of steel needed for the foundations saved the client 20 percent in installation costs.

# Keystone Engineering Designs First Commercial Offshore Wind Farm in the U.S.

Keystone Cuts Design Cycle Time in Half and Reduces Installation Costs by 20 Percent Using SACS Software to Optimize Steel Jacket Foundation Design

## Lowens Energy Costs for Rhode Island Residents

Deepwater Wind, a leading offshore wind developer based in Providence, Rhode Island, undertook the USD 290 million Block Island Wind Farm project to supply less expensive power to Rhode Island. As the first commercial wind farm in the United States, the project demonstrated the feasibility of offshore wind as an alternative energy resource for U.S. coastal cities. Keystone Engineering (Keystone) was retained to design jacket-type substructures for the five, 6-megawatt wind turbine generators.

Keystone used Bentley Systems' SACS software to streamline communication with the generator designer (Alstom), and to model the complex aerodynamic and hydrodynamic loading profile for the deep-water platforms. Bentley's flexible, interoperable offshore design and analysis software shortened the design cycle time by enabling the design team to create simultaneous simulations for multiple design iterations, and helped reduce installation costs by optimizing the substructure design for weight and strength.

## Clean Energy, Big Savings

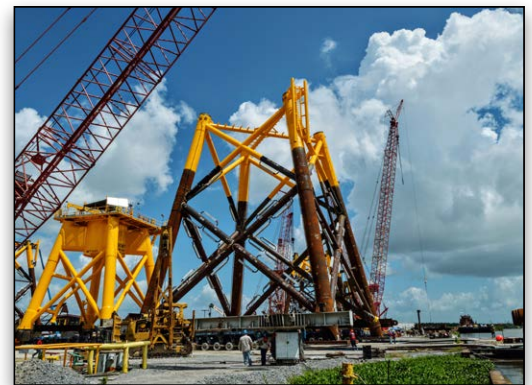
As a clean energy source that is currently cost-competitive with natural gas and nuclear power, onshore wind already represents a \$100 billion investment in the United States. Offshore wind has the added advantage of tapping stronger, more reliable wind resources than onshore wind farms. Deepwater Wind advocates the use of offshore platform technology proven in the oil and gas industry to build wind farms in deep ocean waters miles offshore, where they are barely visible from land yet still close enough to serve major population centers.

Taking the lead from successful offshore wind farms in Europe, Deepwater Wind saw an opportunity to provide cost-competitive energy from wind off the shore of Rhode Island. The Block Island Wind Farm is located 15 miles from the U.S. mainland and 3 miles off the shore of Block Island. It will supply 30 megawatts of power to about 17,000 homes on Block Island via a subsea cable. Due to the otherwise high cost of electricity on the island—currently four to five times

higher than in other U.S. locations—the offshore wind farm is projected to reduce energy costs for Block Island residents by 40 percent, as well as reduce carbon dioxide and other harmful emissions resulting from the diesel generated electric power that is currently used.

## Wind and Wave Loading

The challenge for the team designing the highly dynamic wind turbines involved compensating for the complex loading onto the support structures by both wind and wave action. The design needed to account for the coupled effects of the aerodynamic and hydrodynamic loading, including extreme loading situations such as turbine control faults and hurricane-force winds. To calculate the loads, model the fatigue performance, and engineer the platforms to withstand various load combinations over a 20-year design life, the Keystone team utilized SACS, Bentley's offshore design and analysis software.



*Keystone Engineering designed jacket-type substructures for five wind turbine generators.*

## Oil and Gas Model

As an innovative solution for the design of the deep-water wind turbine support structures, the Keystone team adapted the steel jacket foundation design typically used in the oil and gas industry. Bentley SACS enabled Keystone to design the composite construction and complex nodal geometry of the jacket substructures, delivering an alternative to the typical

*“The Bentley SACS Wind Turbine module allowed us to streamline the analysis process, thereby reducing the design cycle time, the cost to the client, and the risk of errors in managing the tremendous amount of data needed to perform over 3,000 time-domain simulations.”*

*— Zachary Finucane,  
P.E., Project Manager,  
Keystone Engineering Inc.*

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monopile concrete foundations that are limited to offshore wind farms located in more shallow water depths.

To collaborate with the turbine generator designer, Keystone relied on SACS' functionality for interfacing with DNV GL's Bladed, a wind turbine simulation tool. This allowed the team to optimize the design of the total structure and ensure safe operation. The SACS-Bladed interoperability enabled the transfer of simulation model data, ensuring that the models matched.

### **Simultaneous Simulations**

Working on five, 24-core computers running 24 hours-a-day for 10 days, the design team conducted 2,334 simulations, 30 million time steps, and 25 load cases (including operating, storm, start-up, shut-down, fault, maintenance, and installation) for waves of up to 19 meters high and winds from eight directions at speeds from 2 meters per second to 58 meters per second. SACS enabled Keystone to streamline the design and analysis of the simulations, and accurately manage terabytes of project data to minimize the possibility of errors.

Using SACS, Keystone performed more than 3,000 time-domain simulations for each design iteration, and conducted more than 150 simulations in parallel, reducing cycle time by 50 percent compared to typical European offshore wind projects. The SACS-Bladed functionality was also used for tuning the frequency of the structure so that it can operate at a wide band of wind speeds and oceanographic conditions, maximizing revenue. An avoidance band in the operating speed of the turbine could cause losses of production up to 50 percent over the lifetime of the turbine.

### **Reduced Installation Costs**

Keystone leveraged the technology developed for the offshore oil and gas industry to meet the complex design criteria for the jacket foundations. The iterative process optimized the jacket design and reduced the amount of steel needed for the substructure, while still ensuring a design life of more than 20 years. As a result, the Block Island Wind Farm jackets are 15 percent lighter than a previous design used for the same type of wind turbine in the North Sea. The optimized design also reduced installation costs by more than 20 percent compared to traditional monopile construction and can survive hurricane-force winds.

Bentley's comprehensive, interoperable software ensured effective collaboration with the wind turbine designers, facilitating the accurate modeling that produced innovative design solutions throughout the project.

### **Future Savings**

The Block Island Wind Farm will reduce the cost of future offshore wind projects by proving a viable design and fabrication process, and demonstrating the economic feasibility of offshore wind farms in the United States. This first foray into deep waters paves the way for Deepwater Wind's planned 1,000 megawatt offshore wind farm that will be located further offshore for which they hold a federal lease. The project serves as a precedent for a new U.S. industry, supporting infrastructure development to reduce energy costs while significantly expanding job opportunities. By contributing to a diverse energy portfolio, offshore wind will help protect consumers from fuel price spikes and will offset carbon emissions generated by fossil fuels used to generate power.