Transferring Skills and Technologies from Offshore Oil and Gas to Offshore Wind

A Bentley and PennWell Corporation White Paper

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Continuous SACS Evolution

Recently, Bentley has introduced some new algorithms and techniques for offshore monopile structures and their use in shallower waters, so as the size of the tubular members becomes larger, different formulations more accurately predict the wave loads on these structures. Bentley has also taken into account the potential for vessel strikes and the effect it might have on the structural integrity of the jacket. The software engineers accomplished this by simulating vessel strikes from different angles and speeds and creating algorithms to determine the effects. Subsequently, they were able to determine the needed steps within the design phase to eliminate the threat from that specific scenario.

Technology Transfer in a Changing World

Just as the U.S. Space Program gave us technologies initially designed for space travel that morphed into scores of other industries, such is the case with the offshore oil and gas industry. Technologies developed for large offshore oil and gas rigs to withstand wind, wave action, and many other types of harsh marine conditions have been successfully used by the offshore wind industry in Europe, the U.S., and beyond.

Bentley Systems, Incorporated, an Exton, Pennsylvania-based firm, enabled this successful skill and technology transfer through SACS, off-the-shelf structural design software system.

SACS, well-known offshore structural analysis and design software, was developed in parallel with the offshore oil and gas industry in the Gulf of Mexico when that industry segment emerged in the 1970s and expanded in the 1980s. As technology evolved and jackets became larger and were placed in deeper and rougher water, SACS grew concurrently, and the software continues to evolve.

The primary challenge for the offshore wind industry is designing and building structures that can be manufactured and installed easily in order to keep the industry competitive with other forms of power generation. There are lessons to be learned from the shallow-water solutions that were developed for the oil and gas industry and have been in successful operation for decades.

Offshore Oil Down, Offshore Wind Up

As most industry analysts agree, while the onshore sector of the oil and gas industry is ramping up again thanks to the ability to cut operating costs and perform more efficiently than their offshore counterparts, the offshore side has not been as quick to recover. Many analysts predict that offshore oil and gas may not pick up again for another year or two, depending on the stability of oil prices.

This stagnation of offshore work is forcing the more innovative offshore contractors to use their skills elsewhere, and offshore wind needs that type of innovation to make and keep it competitive.

European countries such as the UK, Denmark, Germany, Belgium, and the Netherlands, as well as China, have used skills developed for offshore oil and gas and applied them to wind to become the frontrunners in offshore wind industry.

A similar skill-transfer is beginning to take shape in the United States where the feasibility of such farms in the offshore waters along the East Coast, Hawaii, upper West Coast, and to a lesser extent, the Gulf Coast is being recognized. As with any new industry, the biggest challenge facing the U.S. offshore wind industry is the high upfront infrastructure costs, many of which can be blamed on the lack of a complete supply chain.

SACS for Offshore Wind Explained

SACS Wind Turbine allows users to explore design alternatives for safe, cost effective offshore wind farm structures. The comprehensive, automated capabilities are used to determine environmental and mechanical loading response. Users can reduce risks with integrated analysis for predicting fatigue and extreme loads for substructures and non-linear foundations. Runtime is dramatically reduced for the large number of time history simulations required for fatigue and strength analyses through distribution across multiple processor cores.

By streamlining the design process for offshore wind turbines with both fully coupled and uncoupled analyses, users are able to optimize the interaction between foundations and wind turbines through interface with third-party aeroelastic software, GH Bladed, and FAST, to account for full coupling between wave, wind, and the wind-induced mechanical loading for a multi-modal response analysis.

In Europe, offshore wind already accounts for 10,000 megawatts (10 gigawatts) of grid connected power, with another more than 4,000 megawatts currently under construction. In the 20 years that the European Union has been building offshore wind farms, costs have dropped dramatically and estimates show that the European wind industry will be subsidy-free by 2020. In fact, in April 2017 Germany's electricity grid regulator received and subsequently approved bids for what will be the first offshore wind farms receiving no government support; they will rely completely on market prices.

Companies such as Denmark's DONG Energy, formed in 2006 from the merger of six companies with long histories in oil and gas, has led the European transition to renewable energy. In the last decade, the industry transformed from one of the most coal-intensive utilities in Europe to a global leader in renewable energy, specifically in deploying offshore wind, helping to reduce carbon emissions and harvest Europe's own energy resources. In February 2017, DONG Energy announced that it will stop using coal in all of its power stations by 2023.

In the U.S., analysts estimate 30,000 megawatts (30 gigawatts) of offshore wind capacity could be online domestically by 2030, with a total resource potential of 4,000 gigawatts (4 million megawatts). Analysts also predict that at the current pace, offshore wind will be a USD 200 billion industry by 2030, creating over 43,000 jobs and reducing CO_2 by over 2 million tons.

The majority of the projects in the U.S. are in the planning stages. Most of the projects are located in the eastern U.S., with two in waters off Massachusetts/Rhode Island, two in Maryland, four in New York/New Jersey, and one each in Florida, Virginia, and Delaware.

The biggest success story so far in the domestic offshore wind industry is the Block Island Wind Farm, located off the Rhode Island coast and east of Montauk Point on Long Island, New York.

The Block Island Wind Farm is the first commercial wind farm in the U.S., and it consists of five structures, each one standing over 600 feet tall. The wind farm began commercial operation in December 2016.

Offshore Oil and Gas Engineering Solutions Prove Important for Offshore Wind

Before construction on the Block Island Wind Farm began, engineers were faced with the challenge of designing and building a structure that could withstand strong storms and Nor'easters that frequent the area in summer and winter. Traditional onshore wind farms are anchored into the ground using a system of guy-wires, guy-anchors, and a heavy concrete foundation. This is different than anything located offshore since onshore wind farms only must deal with wind, not the constantly changing forces from wave action an offshore wind farm would regularly face. Therefore, studies were performed to determine the best solution to the problems offshore turbines might face in the day-to-day operating conditions inherent with offshore winds and waves.

The turbines themselves were manufactured by Alstom Wind (now GE Wind), but it was the foundations that needed the most engineering studies. Operating company Deepwater Wind chose Louisiana-based Keystone Engineering to come up with a solution. Keystone is an award-winning engineering firm that developed the Inward

Battered Guide Structure (IBGS), more commonly known as the "Twisted Jacket." The first IBGS was used to support an oil and gas platform in the Gulf of Mexico. It withstood Hurricane Katrina, a 400-year return period metocean condition, with no damage. As a result, the "Twisted Jacket" has become the preferred foundation for two out of three U.S. Department of Energy funded offshore wind projects.

Keystone's experience in fabrication, construction, and installation of offshore structures gave the firm a key advantage in the design stage of the Block Island Wind Farm foundation structure by providing a focus on constructability, fabrication efficiency, and reduced installation time.

Finding an acceptable solution would require thousands of test simulations, and those simulations would require software that was specifically designed for such a purpose.

Keystone selected Bentley Systems SACS software, not only because the two companies had a long history of working together in the offshore oil and gas industry, but also because Bentley was able to partner with Keystone to develop a product specifically for wind turbine structural analysis. Bentley initially got involved in the design of offshore wind farm foundations in China, and subsequently in Europe, and that influenced the evolution of the technology that Bentley utilizes currently.

Thousands of Simulations

Foundation structures for the Block Island Wind Farm had specific and unique requirements, which included being able to withstand a Category 3 hurricane and the ability to compensate for the complex situation of aerodynamic and hydrodynamic loading, as well as any turbine control faults. To do this, meticulous design processes and engineering analysis were required. The four-pile jacket foundation is a common methodology when building offshore oil platforms, but, in addition to the normal situations, these structures had to be engineered to accommodate the additional loading and vibrations from the spinning turbines.

In transferring jacket technology from oil and gas to offshore wind, there were new kinds of loading, which meant a change in the simulation capabilities as well as in the analyses.

The team looked at the different loads that would be reacting on the system and the combination of loads from current, waves, wind, and the actual load on the spinning turbine, all of which combined to create a large number of load cases.

The engineers from Bentley and Keystone took into account the different direction of the wind and the waves and evolved the technology to make it easier to programmatically define the different permutations that must be achieved. This ability will dramatically speed up the computation time.

Software is a critical component of offshore wind farm foundation design for two reasons: One is optimizing the design, making it as efficient as possible, while still complying with the code; and the other is the validation of the final concept and submitting the documentation for approval.

Using Bentley's SACS Wind Turbine software, Keystone ran test simulations, repeating each test with slight variances to make sure the final design could withstand a "1,000-year storm." Different load scenarios and weather conditions were simulated and over 10 million possible test scenarios were performed.

To determine the final structure, Keystone engineers worked on five, 24-core computers operating around the clock for 10 days. They initially conducted almost 2,500 simulations, including more than 30 million time-steps and 25 load cases, which included general operation, start-up, shut-down, installation, storm conditions, and fault maintenance. Using their experience from the oil and gas industry, the engineers covered storm conditions that included waves up to 60 feet and winds from eight different directions at speeds over 125 miles per hour. Bentley's SACS software allowed the engineers to streamline the design and analysis within the simulations and minimize the possibility of any errors.

Once the simulations were complete and all the data was analyzed by the engineers, construction of the jacket foundations began in late 2014. Gulf Island Fabrication, Inc., a company with a history of working with Keystone, was chosen to construct the jackets, decks, and piles for the project, utilizing its many years of experience in the offshore oil and gas industry. Gulf Island specializes in building offshore oil and gas drilling and production platforms, including jacket and deck sections of platforms fixed to the ocean floor. The steel lattices and piles that hold up the Block Island wind turbines share many of the same features as traditional oil and gas offshore structures.

"Transferring the knowledge we gained from oil and gas to renewable energy is exciting. Bentley first became involved in offshore wind farms in China, and subsequently in Europe. That groundbreaking experience influenced the evolution of the SACS technology that we use today, which proved highly successful in Block Island."

– Phil Christensen

Senior Vice President, Analytical Modeling Bentley Systems, Inc.

The first jackets were completed in June 2015 and they began the journey to Rhode Island. The first "loadout" — the process of moving foundation sections from land onto a cargo barge — started on a Friday and wrapped up in just two days without a hitch.

The distance from the yard to the barges was not far since Gulf Island's yards straddle the Houma Navigation Channel, a man-made canal that cuts through the Louisiana bayou and connects to the Gulf of Mexico. The first barge carried two jacket sections, one deck section, and several piles.

Once the jackets left Gulf Island's facility, they travelled approximately 30 miles south to the Gulf of Mexico, continued southeast around Florida, and then turned north toward Block Island, a journey of about 1,800 miles. Installation of the foundations took place in the summer of 2015 and the first turbine was erected in August 2016, with commercial operation beginning in December of that year.

The turbines were put to a real-life test in March 2017, when Winter Storm Stella hit the area, producing winds in excess of 70 miles per hour and causing extreme wave action. Not surprisingly, the asset management systems worked as planned, with the turbines automatically shutting down when the wind reached 55 miles per hour. Once the wind subsided below the cut-off threshold, the system automatically resumed operation without any damage.

Transferring Knowledge Gained in O&G to Wind

The successful use of Bentley's SACS software in the Block Island project was not a surprise. The company had previously developed many different software capabilities for oil and gas, and the products translated seamlessly to offshore wind.

In addition to the staff of experts it already had for the Block Island Project, Bentley hired several veterans of the offshore wind industry from overseas, giving it a well-rounded panel of experts, many of whom had years of experience working on similar projects in China and Europe.

Bentley also partnered with several engineering and construction (E&C) companies overseas, all of whom had extensive experience in designing, testing, and constructing wind farms with similar load expectations.

The SACS software allowed Keystone engineers to explore design alternatives for safe, cost-effective offshore wind farm structures. The automated capabilities let the engineers determine environmental and mechanical loading response, as well as reduce and eliminate the various load risks by utilizing SACS' ability to conduct and report an integrated analysis that can predict fatigue and extreme loads for substructures and non-linear foundations.

Because Keystone's simulations were run on several multi-processor core computers, engineers saw a huge reduction in the runtime usually required for the large number of time history simulations for fatigue and strength analyses.

Presently, it is possible to achieve greater time reduction and inherent cost savings through cloud computing. Cloud computing has raised the bar for shortening the time it takes for completing complex calculations. Bentley has migrated to using the cloud to let its engineers and programmers do thousands of calculations simultaneously in real-time, accelerating the process and, in the end, reducing costs by minimizing the amount of time previously required for extensive calculations.

A Blossoming Market

The Block Island success, coupled with many other offshore wind farm projects either under construction or in the planning stages, might very well serve as a wake-up call for engineering and construction firms as well as individuals in the oil and gas industry that there is something else out there that might have a long-term future with a little more stability.

Most veterans of the offshore oil and gas industry have weathered the rollercoaster ride of the last few decades, and those lucky enough to still be in the business now have a viable option for the transfer of knowledge, experience, and technology in the offshore wind farm arena.

With companies like Bentley and Keystone leading the way, as well as less government regulation, the future looks bright for domestic offshore wind farms.

The experience gained in the oil and gas industry by engineering and construction firms, as well as software solutions providers like Bentley Systems, transfers effortlessly to new developing markets such as offshore wind farms. The results of this transfer of knowledge and technology have already been proven in projects like Block Island, where the end result was an anchored jacket system that is 15 percent lighter than those used in the North Sea; installation costs that were 20 percent less than conventional systems; and products that can withstand the harsh conditions of an offshore wind farm, much like an offshore oil and gas platform. This "new" industry may provide an additional revenue stream for E&C companies while they wait for the offshore oil and gas industry to return to pre-downturn levels.

About Bentley

Bentley Systems is a global leader dedicated to providing engineers, architects, geospatial professionals, constructors, and owner-operators with comprehensive software solutions for advancing the design, construction, and operations of infrastructure.

In offshore, Bentley continues to be a leading provider of engineering software for designing better performing, safer, and more resilient offshore structures. Bentley's innovative technology addresses the key drivers of offshore projects, including risk management, time to first oil, and globalization. Bentley's SACS, MOSES, and MAXSURF software help engineers overcome their most difficult technical challenges by providing excellent control and advanced analysis, design, and simulation capabilities for offshore platforms and vessels.

Together with ProjectWise, Bentley's offshore software solutions enable project teams to work in a distributed and federated environment, ensuring the highest level of collaboration between structural analysis engineers and the rest of the project team.

With AssetWise, Bentley applications ensure a safe, reliable, and compliant operation. Combining 2D/3D intelligent infrastructure models and point clouds with engineering information and asset performance management, Bentley delivers an enterprise platform to manage offshore assets throughout their entire lifecycle. The visual workflow supports both Greenfield and brownfield operations, bridging the gap between CAPEX and OPEX and enabling a sustainable business strategy for operational excellence and safety.

About PennWell Corporation

PennWell Corporation is a global events, media, and marketing services company that has been owned and managed by five generations of the same family for over a century.

Since its founding in 1910 with the publication of the Oil & Gas Journal, which remains today the leading resource for the international oil and gas industry, PennWell Corporation has become a highly-diversified company producing 150 print and online magazines and newsletters, 25 conferences and exhibitions around the world, and an extensive offering of books, maps, websites, research products, digital media, and database services.

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PennWell Corporation's headquarters are in Tulsa, Oklahoma. The company has major offices in Houston, Texas; Nashua, New Hampshire; Fairlawn, New Jersey; La Jolla, California, and London, United Kingdom along with numerous sales offices around the world.

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