Bentley®
*Advancing* Infrastructure

CASE STUDY

# Fujian Yongfu Creates a New Type of Wind Turbine Foundation that Resists Typhoons and Earthquakes

## PLAXIS® and SACS Provided a Unified Environment to Simultaneously Create Models and Test Soil Effect

### INSTALLING ONE OF THE WORLD'S DEEPEST OFFSHORE WIND FACILITIES

As part of China's push to dramatically increase the country's production of renewable energy and reduce the use of carbon-emitting fuels, power generation companies are installing numerous wind facilities off the country's coast. Fujian Yongfu Power Engineering built one of their latest facilities, the China Changle Offshore Wind Farm Area C, 31 kilometers east of Changle, Fujian. The 58.6 square-kilometer area has an average water depth of between 31 and 45 meters, making it one of the world's deepest locations for a wind farm. After an initial feasibility study, the company decided to install 62 wind turbines, each with a capacity of 8 megawatts, for a total capacity of 496 megawatts.

The feasibility study also revealed an array of challenges. For one, the site is frequently battered by typhoons that produce strong winds, turbulence, and frequent wind direction change, which required Fujian Yongfu to develop particularly strong and stable foundations for each turbine. However, they had to design the foundations to accommodate complicated geological conditions, including unstable, soft soil, as well as the strong possibility of earthquakes that could have a magnitude as high as seven on the Richter scale. The project's extreme depth also required the design team to adapt permanent and temporary construction structures to changing conditions and keep construction vessels safe. However, as Fujian Yongfu faced budget restraints, they needed to find a way to design the facility safely while keeping costs under control.

*Compared to more traditional offshore wind turbine designs, the solution reduces costs by 30%, or more than CNY 400 million.*

### DIFFICULTIES DESIGNING WITH TRADITIONAL METHODS

Fujian Yongfu determined that the best way to keep the facility strong and stable was to build the foundations with suction pile frames. Suction piles are long cylinders topped with a cap, with valves to assist with the process of embedding them in the soil. The advantage of these foundations is that they can penetrate up to 60% of their length into the ocean floor just by using their own weight, depending on soil conditions. Though suction piles have been used for various offshore structures since the 1990s, they had not been deployed as foundations for offshore wind turbines. Therefore, Fujian Yongfu could not rely on previous experience and had to engineer a solution themselves.

The design team soon discovered that they also could not rely on traditional methods of offshore wind design. Their initial attempt with these methods could not accurately simulate the interaction between the soil and a pile with such a large diameter, producing an overly conservative design that would have significantly increased the cost of the project. Fujian Yongfu then tried to use separate digital simulations of the interaction between the pile and the soil and the design of the frame itself, but they learned that the two separate results were difficult to unify. They needed digital design software that could unify soil analysis and digital foundation design to determine how to effectively use the suction pile method for wind turbines.

## PROJECT SUMMARY

### ORGANIZATION
Fujian Yongfu Power Engineering Co., Ltd.

### SOLUTION
Mining and Offshore Engineering

### LOCATION
Changle, Fujian, China

### PROJECT OBJECTIVES
- To develop a wind facility in a geographically complicated area.
- To unify modeling and soil analysis to deploy a new type of foundation.

### PROJECT PLAYBOOK
PLAXIS, OpenWindPower® Fixed Foundation

## FAST FACTS
- Fujian Yongfu Power Engineering needed to build a large wind farm in an area prone to typhoons, earthquakes, and shifting soil.
- Initial work with traditional methods produced expensive designs, and other digital solutions could not unify modeling and soil analysis.
- The design team used PLAXIS and OpenWindPower Fixed Foundation to simultaneously model potential foundation options and analyze its effects on the ocean soil.

## ROI
- Compared to more traditional offshore wind turbine designs, the solution reduces costs by 30%, or more than CNY 400 million.
- The wind farm eliminates the use of 535,000 tons of coal annually and cuts carbon dioxide emissions by 1,462,600 tons.
- The design helped minimize environmental impact by sustaining water quality, minimizing erosion, and protecting marine and avian life.

"OpenWindPower Fixed Foundation and PLAXIS allows engineers to take advantage of their seamless interface to optimize the design of wind turbine foundation structures such as single pile and suction pile."

*-Fan Xia Ling, Engineering, Fujian Yongfu Power Engineering Co., Ltd.*

## DETERMINING THE BEST DESIGN WITH UNIFIED SOFTWARE

Though Fujian Yongfu had previously used Bentley's OpenWindPower Fixed Foundation for offshore modeling, they discovered that pairing it with PLAXIS would give them a unified design environment that could allow them to perform soil analysis and foundation design at the same time. Additionally, recent advancements in the applications included an integrated offshore structural and geotechnical design process for the design of large diameter monopiles and suction tubes, which would enable the design team to fully realize and optimize their design intent.

They first used PLAXIS to perform a full analysis of the soil in the construction area that could also measure the potential effects of design options. Within that environment, they then simultaneously formed and optimized the design of the foundation in OpenWindPower Fixed Foundation while examining how the current state of the design would interact with the soil. The design team used a suction pile module within SACS to automatically import PLAXIS analysis and create a composite model, which shows both the current state of the model and its effects on the soil around it. With this information, they adjusted the model to increase its strength and stability.

*Fujian Yongfu Power Engineering needed to build a large wind farm in an area prone to typhoons, earthquakes, and shifting soil.*

## KEEPING WIND TURBINES SAFE DURING TYPHOONS

As a result of synchronized soil analysis and digital modeling, Fujian Yongfu determined that the best type of foundation for the project would be a three-pile suction conduit frame. Though this type of frame had only been used in experimental environments within China, Fujian Yongfu used Bentley software to build it on a large scale and demonstrate its utility. Since this type of pile has a larger diameter but a shorter length than other piles typically used for offshore wind facilities, they reduced the amount of steel needed for each foundation. Additionally, the design makes construction faster and easier, as it solves the problem of fatigue damage during pile driving and eliminates the need for some staging platforms and larger construction equipment such as pile driving vessels.

By determining the feasibility of the three-pile suction conduit frame foundations, Fujian Yongfu ensured the wind turbines can withstand typhoons, shifting soil, and earthquakes. Compared to more traditional offshore wind turbine designs, the solution reduces costs by 30%, or more than CNY 400 million. Establishing 496 megawatts of clean energy in Fujian will eliminate the need to burn 535,000 tons of coal annually and cut down on carbon dioxide emissions from various power generation sources by 1,462,600 tons. The design also helped Fujian Yongfu minimize environmental impact by sustaining water quality, minimizing erosion, and protecting marine and avian life.


*The wind farm eliminates the use of 535,000 tons of coal annually and cuts down on carbon dioxide emissions from various power generation sources by 1,462,600 tons.*