Renewables, Asia - Timeline

2010

COMMISSION OF THE DONGHAI BRIDGE OFFSHORE WIND FARM

It was the first offshore wind farm in Asia and the first built outside Europe. A high rise pile cap foundation was developed to deal with very thick soft clays and has since been sucessfully applied in many offshore wind farms in China and overseas (e.g. Vietnam).

2010

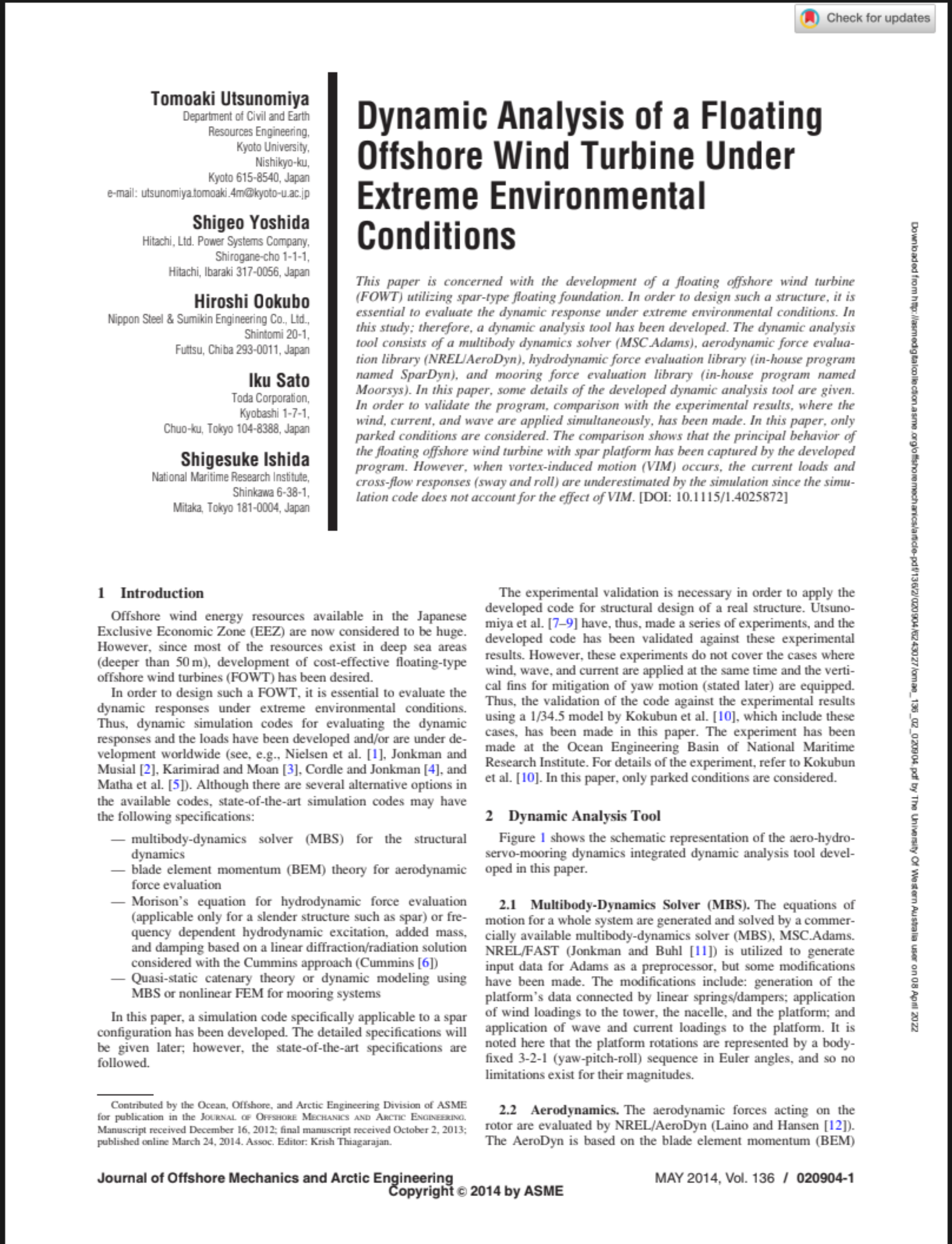
INSTALLATION OF THE FIRST COMPOSITE BUCKET FOUNDATION

A large diameter composite bucket foundation (CBF) was installed at the offshore test facility in Qidong City in the eastern part of Jiangsu Province. The wind turbine was a XEMC 2.5 MW unit with an 80 m hub height. The diameter of the CBF was 30 m and the skirt height was 7 m. The total foundation weight was nearly 2200 t and the arc transition structure made of pre-stressed concrete was 18 m high. The CBF concept combined the features of gravity foundation and a suction bucket foundation and was installed to full depth originally by self-weight and subsequently by underpressure.

2012

CONSTRUCTION OF THE JIANGSU RUDONG OFFSHORE (INTERTIDAL) WIND FARM - FIRST USE OF MONOPILES TO SUPPORT OFFSHORE WIND TURBINES IN CHINA

The 150 MW Jiangsu Rudong Offshore (Intertidal) Wind Farm was situated in an intertidal area of the East China Sea, approxiamtely 3-8 km away from the shore. The location was dry at low tide but was covered by up to 5 m of water at high tide. The project was divided into two phases. The 100 MW Phase 1 was founded on multi-pile foundation, the 50 MW Phase 2 was founded on 5.2 m diameter monopile foundations.



Check for updates

Tomoaki Utsunomiya
Department of Civil and Earth Resources Engineering,
Kyoto University,
Nishikyo-ku,
Kyoto 615-8540, Japan
e-mail: utsunomiya.tomoaki.4m@kyoto-u.ac.jp

Shigeo Yoshida
Hitachi, Ltd. Power Systems Company,
Shirogane-cho 1-1-1,
Hitachi, Ibaraki 317-0056, Japan

Hiroshi Ookubo
Nippon Steel & Sumikin Engineering Co., Ltd.,
Shintomi 20-1,
Futtsu, Chiba 293-0011, Japan

Iku Sato
Toda Corporation,
Kyobashi 1-7-1,
Chuo-ku, Tokyo 104-8388, Japan

Shigesuke Ishida
National Maritime Research Institute,
Shinkawa 6-38-1,
Mitaka, Tokyo 181-0004, Japan

Dynamic Analysis of a Floating Offshore Wind Turbine Under Extreme Environmental Conditions

This paper is concerned with the development of a floating offshore wind turbine (FOWT) utilizing spar-type floating foundation. In order to design such a structure, it is essential to evaluate the dynamic response under extreme environmental conditions. In this study; therefore, a dynamic analysis tool has been developed. The dynamic analysis tool consists of a multibody dynamics solver (MSC.Adams), aerodynamic force evaluation library (NREL/AeroDyn), hydrodynamic force evaluation library (in-house program named SparDyn), and mooring force evaluation library (in-house program named Moorsys). In this paper, some details of the developed dynamic analysis tool are given. In order to validate the program, comparison with the experimental results, where the wind, current, and wave are applied simultaneously, has been made. In this paper, only parked conditions are considered. The comparison shows that the principal behavior of the floating offshore wind turbine with spar platform has been captured by the developed program. However, when vortex-induced motion (VIM) occurs, the current loads and cross-flow responses (sway and roll) are underestimated by the simulation since the simulation code does not account for the effect of VIM. [DOI: 10.1115/1.4025872]

1 Introduction

Offshore wind energy resources available in the Japanese Exclusive Economic Zone (EEZ) are now considered to be huge. However, since most of the resources exist in deep sea areas (deeper than 50 m), development of cost-effective floating-type offshore wind turbines (FOWT) has been desired.

In order to design such a FOWT, it is essential to evaluate the dynamic responses under extreme environmental conditions. Thus, dynamic simulation codes for evaluating the dynamic responses and the loads have been developed and/or are under development worldwide (see, e.g., Nielsen et al. [1], Jonkman and Musial [2], Karimirad and Moan [3], Cordle and Jonkman [4], and Matha et al. [5]). Although there are several alternative options in the available codes, state-of-the-art simulation codes may have the following specifications:

— multibody-dynamics solver (MBS) for the structural dynamics
— blade element momentum (BEM) theory for aerodynamic force evaluation
— Morison's equation for hydrodynamic force evaluation (applicable only for a slender structure such as spar) or frequency dependent hydrodynamic excitation, added mass, and damping based on a linear diffraction/radiation solution considered with the Cummins approach (Cummins [6])
— Quasi-static catenary theory or dynamic modeling using MBS or nonlinear FEM for mooring systems

In this paper, a simulation code specifically applicable to a spar configuration has been developed. The detailed specifications will be given later; however, the state-of-the-art specifications are followed.

The experimental validation is necessary in order to apply the developed code for structural design of a real structure. Utsunomiya et al. [7–9] have, thus, made a series of experiments, and the developed code has been validated against these experimental results. However, these experiments do not cover the cases where wind, wave, and current are applied at the same time and the vertical fins for mitigation of yaw motion (stated later) are equipped. Thus, the validation of the code against the experimental results using a 1/34.5 model by Kokubun et al. [10], which include these cases, has been made in this paper. The experiment has been made at the Ocean Engineering Basin of National Maritime Research Institute. For details of the experiment, refer to Kokubun et al. [10]. In this paper, only parked conditions are considered.

2 Dynamic Analysis Tool

Figure 1 shows the schematic representation of the aero-hydro-servo-mooring dynamics integrated dynamic analysis tool developed in this paper.

2.1 Multibody-Dynamics Solver (MBS). The equations of motion for a whole system are generated and solved by a commercially available multibody-dynamics solver (MBS), MSC.Adams. NREL/FAST (Jonkman and Buhl [11]) is utilized to generate input data for Adams as a preprocessor, but some modifications have been made. The modifications include: generation of the platform's data connected by linear springs/dampers; application of wind loadings to the tower, the nacelle, and the platform; and application of wave and current loadings to the platform. It is noted here that the platform rotations are represented by a body-fixed 3-2-1 (yaw-pitch-roll) sequence in Euler angles, and so no limitations exist for their magnitudes.

2.2 Aerodynamics. The aerodynamic forces acting on the rotor are evaluated by NREL/AeroDyn (Laino and Hansen [12]). The AeroDyn is based on the blade element momentum (BEM)

Contributed by the Ocean, Offshore, and Arctic Engineering Division of ASME for publication in the Journal of Offshore Mechanics and Arctic Engineering. Manuscript received December 16, 2012; final manuscript received October 2, 2013; published online March 24, 2014. Assoc. Editor: Krish Thiagarajan.

2013
INSTALLATION OF THE HAENKAZE (SAKIYAMA) 2MW FLOATING OFFSHORE WIND TURBINE - FIRST COMMERCIAL SCALE FLOATING WIND TURBINE IN ASIA

The Haenkaze 2 MW floating offshore wind turbine is the first commercial scale floating facility for both Japan and Asia. It was installed sucessfully on October 28, 2013 off the coast of Kabashima, Goto City. It is supported by a hybrid spar structure (upper part is made of steel and the lower part is made of concrete). After two years of operation, it was relocated to a site off the coast of Sakiyama in 2015.

2013

GRID CONNECTION OF THE BAC LIEU PHASE 1 OFFSHORE (INTERTIDAL) WIND FARM - FIRST OFFSHORE WIND FARM IN THE MEKONG DELTA REGION

The wind farm is located in a submerged coastal area of Vinh Trach Dong Commune in Bac Lieu city. The first stage included installation of 10 1.6-MW turbines supplied by General Electric and was grid connected in May 2013. The second stage of the project saw the installation of 52 1.6-MW turbines and the entire wind farm became fully operational in January 2016.

2016

INSTALLATION OF THE FIRST PILED JACKET AT ZHUHAI GUISHAN OFFSHORE WIND FARM

In September 2016, the first quadpod jacket structure on pile foundations was installed at the Zhuhai Guishan Offshore Wind Farm at the river mouth of the Pearl River in 13-35 m thick of soft clay. The jacket structure has a leg spacing of 15 m and is 30 m in height. Each jacket weighs about 450 tonnes (excluding pile foundations). Each jacket supports a 3MW wind turbine.

energies

MDPI

Article

Study on the Bearing Mode and Force Transfer Path of Composite Bucket Foundations

Shaohua He [2], Puyang Zhang [1,2,*] and Hongyan Ding [1,2]

1 State Key Laboratory of Hydraulic Engineering Simulation and Safety, Tianjin University, Tianjin 300072, China; dhy_td@163.com
2 School of Civil Engineering, Tianjin University, Tianjin 300072, China; hsh_td@163.com
* Correspondence: zpy@tju.edu.cn

Academic Editor: Lance Manuel
Received: 13 June 2017; Accepted: 18 July 2017; Published: 20 July 2017

Abstract: This paper elaborates on a new composite bucket foundation (CBF) structural system for offshore wind turbines. The proposed CBF consists of a special force transition section, a beam system structure upper steel bucket cover and a large-scale steel bucket with honeycomb structure rooms. It can be prefabricated onshore, self-floated on the sea and then towed to the appointed sea area before sinking to the sea soil under negative pressure. This is called the "one-step" installation technology. Arc- and line-type bucket foundations are calculated by both theory and the finite element method to discuss their force transfer paths and bearing modes. Owning to the special structural form, the transition section can effectively convert the huge load and bending moment into controllable tension and compressive stress, as well as adjust the structure balance. The bearing model and percentage of each part of the composite foundation under monotonous and ultimate load conditions are also calculated. Results indicate that the bearing mode of CBF is a typical top cover mode. In addition, the curvature impact of arc-type is studied and the results reveal that the structure type of the transition section is more important than the diameter ratio between the bottom transition section and the bucket.

Keywords: wind energy; composite bucket foundation; transfer segment; load transfer characteristic; bearing mechanism

1. Introduction

Offshore wind turbines are a new frontier in wind power development. Their foundations are significantly affected by the horizontal force and large bending moment at the top. Considering the mechanical properties, cost-effectiveness, and construction feasibility, the main forms of offshore wind turbine structures usually consist of concrete structures, such as elevated pile caps, monopile foundations, and gravity foundations. Bucket foundations are a new type of foundation currently used in offshore wind power construction. They are also called suction anchors, because they used to be applied to the mooring system as a suction pile. The bucket foundation looks like an inverted cup that is closed at the top and opened at the bottom. Steel bulkheads divide the seven rooms inside the composite bucket foundation (CBF). Hence, it is a relatively special construction layout, whose main mechanism is based on the principle of negative pressure penetration.

In recent years, studies on bucket foundations have been carried out in China and abroad. Helfrich et al. [1] first carried out a model test in sand to study the characteristics and failure modes of suction anchors, and provided test data associated with a 400-mm diameter suction anchor. Le et al. [2] presented the bearing capacities of bucket foundations in normally consolidated uniform clay under undrained conditions, and reported that the vertical capacity consisted of an end-bearing resistance and a skin friction resistance, whereas the horizontal capacity consisted of a normal resistance, a radial

2017

FIRST INTEGRATED FLOATING INSTALLATION OF AN OFFSHORE WIND TURBINE SUPPORTED BY COMPOSITE SUCTION BUCKET FOUNDATION AT XIANGSHUI OFFSHORE WIND FARM

In 2017, the first integrated floating foundation-tower-turbine was successfully installed at the Xiangshui Offshore Wind Farm. The entire offshore wind structure was assembled in the harbor and towed to site using a purpose-built vessel. The composite suction bucket foundation has an overal diameter of 30 m and skirt height of 12 m. The transition section is 18.8 m in height. The entire foundation weighs 2350 tonnes. Installation of a single onsite turbine took 10 hours to position.

2020

INSTALLATION OF THE FIRST QUADPOD SUCTION BUCKET JACKET FOR AN OFFSHORE WIND TURBINE AT DALIAN ZHUANGHE OFFSHORE WIND FARM SITE II PROJECT

The first of its kind in China - designed to withstand sea ice loading.

2020

INSTALLATION OF THE FIRST TRIPOD SUCTION BUCKET JACKET FOR AN OFFSHORE WIND TURBINE IN TYPHOON-PRONE SOUTH CHINA SEA

The first of three suction bucket jackets were sucessfully installed at the China Three Gorges New Energy Yangjiang Shapa Phase 1 Offshore Wind Farm in August 2020. It was the first of its type in typhoon-prone Southern China. Significant research efforts were made to design the foundation to withstand extreme typhoon loading and long term servicability deformation.

2020

INSTALLATION OF FIRST QUADPOD JACKET STRUCTURE ON LARGE DIAMETER DRIVEN PILES AT CHINA THREE GORGES NEW ENERGY SHAPA OFFSHORE WIND FARM PHASE 2 PROJECT.

In June 2020, the first quadpod jacket structure founded on large diameter driven piles was sucessfully installed at the China Three Gorges New Energy Shapa Offshore Wind Farm Phase 2 project. The geotechnical conditions at the wind farm featured extremely soft soils and shallow bed rock. Due to the expense associated with using conventional pile jackets for socket piling in rock, a large diameter piled jacket foundation was developed. The diameter of the piles ranged from 4 to 5 m, with a smallest penetration depth of less than 30m. The jackets were used to support 6.45 MW turbines.

2020

CONSTRUCTION OF THE SHANDONG LAIZHOU BAY WIND FARM - CHINA'S FIRST WIND-AND-AQUACULTURE HYBRID PROJECT

The 300MW Laizhou Bay Phase I started construction in Shandong Province in 2020 and used turbine foundations as artificial reefs for aqua-farming. It is a first-of-its-kind project for China.

2021

INSTALLATION OF THE THREE GORGES FLOATING WIND TURBINE - THE WORLD'S FIRST TYPHOON-RESISTANT FLOATING OFFSHORE WIND TURBINE

In July 2021, China Three Gorges New Energy, sucessfully installed China's first floating offshore wind turbine as part of the Shapa Offshore Wind Farm Phase 3 Project. The floater was based on semi design and was anchored to the seabed by 9 suction caissons. The floater supports a 5.5 MW turbine and was designed to resist typhoons up to category 17. The water depth at the site was approximately 28 m.