Foundations For Offshore Wind Turbines

Offshore wind energy is one of the primary renewable sources of energy. The ongoing development of the capacity and distance to shore of offshore wind turbines (OWTs) lead to more severe loading conditions. The substructures for OWTs are required to be capable of withstanding the combined loads with vertical loads from the weight of upper structures, and relatively high lateral loads and resultant moments induced by waves, winds, ice and currents. Two types of innovative foundations: the suction bucket foundation and monopile-friction wheel foundation are investigated in this dissertation via centrifuge modellings and finite element (FE) analyses.Suction bucket foundations are a promising foundation option for offshore wind turbines. To assess the lateral-moment loading capacity of bucket foundations, a group of 3-D finite element (FE) simulations with different bucket dimensions in sand and clay is carried out based on the centrifuge model tests. The numerical methods are validated by comparisons with the results of centrifuge tests, and assessed by sensitivity analyses regarding the influences of soil properties and soil-foundation interface parameters. The interaction between the bucket and surrounding soil is illustrated in order to demonstrate the bearing behavior and failure mechanism of the bucket foundation. It is shown that in the ultimate state, the maximum passive earth pressure acting on the external skirt in the loading direction is approximately 4 times larger than that on the internal skirt. Furthermore, parametric studies on the L/D ratios (L is the skirt length and D is the bucket diameter) and loading eccentricity are conducted and discussed. Consequently, a modified calculation method is proposed to predict the ultimate lateral-moment loading capacity of bucket foundations in sand. The method is validated by field and laboratory test data.The monopile-friction wheel foundation integrates a wheel to a monopile to improve the lateral performance. Two types of wheels, the solid wheel and gravel wheel, are discussed in this part. A series of tests on the monopile, hybrid foundations with solid wheels of different diameters and thicknesses, and single solid wheel foundation were conducted. The results show that the lateral bearing capacity and stiffness increase significantly by adding a solid wheel to the monopile, and the improvement is related to the diameter and thickness of the wheel. An extensive experimental research regarding to the influential factors such as the embedment of the wheel and the vertical load is also presented. By means of FEM, the load transfer mechanism, interaction between the foundation and soil, and the bending moment in the pile are illustrated to study how the solid wheel contributes to the performance of the foundation system. Moreover, the effects of load eccentricity and vertical load are investigated by FEM analyses.The gravel wheel is a ring frame filled with large particles to potentially utilize the gravel or crushed stones in offshore areas. The results of centrifuge tests and FEM analyses demonstrate that the lateral loading capacity of the monopile increases when combined with a gravel wheel, and the improvement depends on the diameter and thickness of the wheel. By means of FEM, the interaction between the pile and surrounding soils and gravel fill are illustrated to interpret the effect of the gravel wheel on the hybrid system. Furthermore, an equivalent layer method adopting the conventional p-y curves is suggested to predict the lateral response of the hybrid foundation. This method is validated by comparisons with the centrifuge tests results. Finally, a case study of the monopile-gravel wheel foundation indicates that the gravel wheel is less efficient in configurations where the ultimate capacity of the hybrid system is dictated by the bending capacity of structures rather than the strengths of soils.

[Truncated abstract] The demand for offshore wind turbines is increasing in densely populated areas, such as Europe. These constructions are typically founded on a gravity foundation or a large 'mono pile'. Gravity foundations can only be used at locations where strong soils exist and water depths are limited. Costs associated with a 'mono pile' type foundation contribute to a very large percentage of the total investment costs. This research, therefore, focuses upon a different foundation for offshore wind turbines, namely suction caissons beneath a tripod. This foundation can be used in all kinds of soil types and is cheaper than the 'mono pile' foundation, both in the amount of steel used and installation costs. Cheaper foundations can contribute to a more competitive price for offshore wind energy in comparison with other energy resources. To date, there have been relatively few studies to investigate the behaviour of this type of foundation during the installation process and during operational and ultimate loading for seabed conditions comprising dense sand. Two types of investigations were performed during this research to determine the behaviour of suction caissons beneath a tripod. Firstly, an existing computer program was extended to predict the typical loading conditions for a tripod foundation. Secondly, centrifuge tests on small scale suction caissons were performed to investigate the behaviour during the installation and loading phases. The computer program developed helped to quantify the likely ranges of environmental loading on an offshore wind turbine. For a typical 3 MW wind turbine of 90 m height, the vertical load is low at around 7 MN. During storm conditions the horizontal hydrodynamic load can be in the order of 4 MN. During normal working conditions the horizontal aerodynamic loads can reach 0.4 MN, but can increase to 1.2 MN when the pitch system malfunctions and gusts reach 30 m/s. This aerodynamic load will result in a very large contribution to the overturning moment, due to the high action point of this load. When the wind turbine is placed on top of a tripod, these large moments are counteracted by a push-pull system. ... The development of differential pressure was found to depend on the soil permeability, the extraction speed and a consolidation effect. During cyclic loading no obvious signs of a decrease in resistance were observed. During very fast cyclic loading differential pressures developed, which could increase the drained frictional resistance by approximately 40%. All centrifuge tests results were used to develop methods to predict or back calculate the installation process of suction caissons in sand and layered soil, and the behaviour during tensile and cyclic loading. These methods all use the cone resistance as the main input parameter and predict the force (or required suction) as a function of time, for a given rate of pumping or uplift displacement, in addition to the variation of suction with penetration (or force with uplift displacement). These new methods provide a useful tool in designing a reliable foundation for offshore wind turbines consisting of a tripod arrangement of suction caissons

embedded in dense sand.

Offshore Wind Farms: Technologies, Design and Operation provides the latest information on offshore wind energy, one of Europe’s most promising and quickly maturing industries, and a potentially huge untapped renewable energy source which could contribute significantly towards EU 20-20-20 renewable energy generation targets. It has been estimated that by 2030 Europe could have 150GW of offshore wind energy capacity, meeting 14% of our power demand. Offshore Wind Farms: Technologies, Design and Operation provides a comprehensive overview of the emerging technologies, design, and operation of offshore wind farms. Part One introduces offshore wind energy as well as offshore wind turbine siting with expert analysis of economics, wind resources, and remote sensing technologies. The second section provides an overview of offshore wind turbine materials and design, while part three outlines the integration of wind farms into power grids with insights to cabling and energy storage. The final section of the book details the installation and operation of offshore wind farms with chapters on condition monitoring and health and safety, amongst others. Provides an in-depth, multi-contributor, comprehensive overview of offshore technologies, including design, monitoring, and operation Edited by respected and leading experts in the field, with experience in both academia and industry Covers a highly relevant and important topic given the great potential of offshore wind power in contributing significantly to EU 20-20-20 renewable energy targets

The wind energy industry in Germany has an excellent global standing when it comes to the development and construction of wind turbines. Germany currently represents the world's largest market for wind energy. The ongoing development of ever more powerful wind turbines plus additional requirements for the design and construction of their offshore foundation structures exceeds the actual experiences gained so far in the various disciplines concerned. This book gives a comprehensive overview for planning and structural design analysis of reinforced concrete and pre-stressed concrete wind turbine towers for both, onshore and offshore wind turbines. Wind turbines represent structures subjected to highly dynamic loading patterns. Therefore, for the design of loadbearing structures, fatigue effects - and not just maximum loads - are extremely important, in particular in the connections and joints of concrete and hybrid structures. There multi-axial stress conditions occure which so far are not covered by the design codes. The specific actions, the nonlinear behaviour and modeling for the structural analysis are explained. Design and verification with a focus on fatigue are adressed. The chapter Manufacturing includes hybrid structures, segmental construction of pre-stressed concrete towers and offshore wind turbine foundations. Selected chapters from the German concrete yearbook are now being published in the new English "Beton-Kalender Series" for the benefit of an international audience. Since it was founded in 1906, the Ernst & Sohn "Beton-Kalender" has been supporting developments in reinforced and prestressed concrete. The aim was to publish a yearbook to reflect progress in "ferro-concrete" structures until - as the book's first editor, Fritz von Emperger (1862-1942), expressed it - the "tempestuous development" in this form of construction came to an end. However, the "Beton-Kalender" quickly became the chosen work of reference for civil and structural engineers, and apart from the years 1945-1950 has been published annually ever since.

This book provides a holistic, interdisciplinary overview of offshore wind energy, and is a must-read for advanced researchers. Topics, from the design and analysis of future turbines, to the decommissioning of wind farms, are covered. The scope of the work ranges from analytical, numerical and experimental advancements in structural and fluid mechanics, to novel developments in risk, safety & reliability engineering for offshore wind.The core objective of the current work is to make offshore wind energy more competitive, by improving the reliability, and operations and maintenance (O&M) strategies of wind turbines. The research was carried out under the auspices of the EU-funded project, MARE-WINT. The project provided a unique opportunity for a group of researchers to work closely together, undergo multidisciplinary doctoral training, and conduct research in the area of offshore wind energy generation. Contributions from expert, external authors are also included, and the complete work seeks to bridge the gap between research and a rapidly-evolving industry.

This four-volume set, edited by a leading expert in the field, brings together in one collection a series of papers that have been fundamental to the development of renewable energy as a defined discipline. Some of the papers were first published many years ago, but they remain classics in their fields and retain their relevance to the understanding of current issues. The papers have been selected with the assistance of an eminent international editorial board. The set includes a general introduction and each volume is introduced by a new overview essay, placing the selected papers in context. The range of subject matter is considerable, including coverage of all the main renewable technologies, the fundamental principles by which they function, and the issues around their deployment such as planning, integration and socio-economic assessment. Overall, the set provides students, teachers and researchers, confronted with thousands of journal articles, book chapters and grey literature stretching back decades, with a ready-made selection of and commentary on the most important key writings in renewable energy. It will be an essential reference for libraries concerned with energy, technology and the environment.

Comprehensive reference covering the design of foundations for offshore wind turbines As the demand for “green” energy increases the offshore wind power industry is expanding at a rapid pace around the world. Design of Foundations for Offshore Wind Turbines is a comprehensive reference which covers the design of foundations for offshore wind turbines, and includes examples and case studies. It provides an overview of a wind farm and a wind turbine structure, and examines the different types of loads on the offshore wind turbine structure. Foundation design considerations and the necessary calculations are also covered. The geotechnical site investigation and soil behavior/soil structure interaction are discussed, and the final chapter takes a case study of a wind turbine and demonstrates how to carry out step by step calculations. Key features: New, important subject to the industry. Includes calculations and case studies. Accompanied by a website hosting software and data files. Design of Foundations for Offshore Wind Turbines is a must

have reference for engineers within the renewable energy industry and is also a useful guide for graduate students in this area.

Intermediate foundations are used as anchors for floating platforms and ancillary structures, foundations for steel jackets, and to support seafloor equipment and offshore wind turbines. When installed by suction, they are an economical alternative to piling, and also may be completely removed. They are usually circular in plan and are essentially rigid when laterally loaded. Length to diameter embedment ratios, L/D, generally vary between 0.5 and 10, spanning the gap between shallow and deep foundations, although these are indicative boundaries and the response, rather than the embedment ratio, defines an intermediate foundation. The first chapters introduce foundation types; compare shallow, intermediate and deep foundation models and design; define unique design issues that make intermediate foundations distinct from shallow and deep foundations, as well as list their hazards that mainly occur during installation. Later chapters cover installation, in-place resistance and in-place response, and miscellaneous design considerations. There is no general agreement as to which design methods/models are appropriate, so models should only be as accurate as the data. Therefore, several reasonably accurate models are provided together with comprehensive discussion and advice. Example calculations and over 200 references are also included. This is the first book dedicated to the geotechnical design of intermediate foundations, and it will appeal to professional engineers specialising in the offshore industry.

"This book uses academic content and rigor to introduce all relevant topics, from global wind resource and historical background, through to modern electricity generation and distribution, including the topical subject area of offshore systems"--

This Limited Edition combines part 1 & 2 of Building an Offshore Wind Farm - Operational Master Guide.The Operational Master Guide on Building an Offshore Wind Farm part 1 is the first book available on the market to specifically focus on the installation of an offshore wind farm. The book draws on the author's hands on experience of the transport and installation of the components for the offshore wind farms. The book also specifies the type of construction vessels used for each specific installation, outlines the required crew members on board and their mandatory basic training programs and explains how the workers travel to and from site. The Operational Master Guide on Building an Offshore Wind Farm Part 2 - Floating Structures is the sequel of the Operational Master Guide on Building an Offshore Wind Farm and is the first book available to the public to specifically focus on the installation of a floating offshore wind farm. Floating Offshore Wind Foundations unlock new renewable energy potential. Average wind speeds are higher and more consistent further from shore and around 80% of Europe's offshore wind resources is located in waters of more than 60 meter depth, where bottom-fixed offshore wind structures are not economically attractive. This means floating offshore wind farms can produce more energy throughout the year and have high capacity factors. Some of the largest potential markets, such as Japan and the United States, possess few shallow-water sites suitable for offshore wind development. Floating foundations could be game changers for power generation from deeper waters as they eliminate the depth constraint. Floating Offshore Wind Structures also open new markets Europe (France, Norway, Spain and Portugal) for the offshore wind energy industry and allows for the harnessing of great wind resources in shallower waters (as low as 30m) where the seabed quality makes bottom fixed offshore wind economically unviable.The book draws on integrated research and the author's experience within the sector and is a valuable educational investment designed with graphics and figures along with corresponding project photos which creates an easy read and provides the readers with a quick, but yet deep understanding on the respective installation phases.

Offshore Wind is the first-ever roadmap to successful offshore wind installation. It provides a ready reference for wind project managers, teaching them how to deal with complications on-site, as well as for financers, who can utilize the text as an easy guide to asking the pivotal questions of petitioning wind project developers. These developers' planning stages will be improved by the book's expert advice on how to avoid wasting money by scoping out and mitigating potential problems up-front. Wind turbine manufacturers will benefit from insights into design optimization to support cheaper installation and hauling, thereby incurring lower project costs, and helping developers establish a quicker route to profitability. The book sheds light not just on how to solve a particular installation difficulty, but delves into why the problem may best be solved in that way. Enables all stakeholders to realize cheaper, faster, and safer offshore wind projects Explains the different approaches to executing on- and offshore projects, highlighting the economic impacts of the various financial and operational choices Provides practical, proven advice on how tough challenges can be overcome, using real-life examples from the author’s experiences to illustrate key issues

The wind is a clean, free, and readily available renewable energy source which can be converted into electricity using wind turbines that convert the kinetic energy from the wind into mechanical power. Windspeed and direction are more consistent offshore than they are onshore and consequently, offshore wind farms are built progressively. Statistics from Wind Europe confirm that 2018 counted a total of 4,543 installed and grid connected offshore turbines in Europe corresponding to a total of capacity of 18,499 MW.The Operational Master Guide on Building an Offshore Wind Farm is the first book available to the public to specifically focus on the installation of an offshore wind farm. The book draws on the author's experience of the transport and installation of the components for the offshore wind farms. It also specifies the type of installation vessels used for the specific installations, outlines the required crew members on board and their mandatory basic training programs and explains how the workers travel to and from site.This book is a valuable educational investment designed with graphics and figures along with corresponding project photos which creates an easy read and provides the readers with a quick, but yet deep understanding on the respective installation phases.The authors, Jochem Tacx and Integrated-TIS:Jochem T. started his career working at the shipyard Keppel Verolme, in the port of Rotterdam, and later specializing within the transport and installation of heavy, high value and oversized project equipment. During his career Jochem has represented the interest of the main clients and first-tier contractors by fulfilling all aspects of project- and related QHSE management. His career enabled him to work on all phases of the respective offshore wind farm installations including the installation of the foundations, laying of the submarine power cables and installing the wind turbines.Integrated-TIS is an international service provider for the energy industry specialized within the transport and installation of heavy, high value and high volume industrial components. Integrated-TIS provides project consulting, project management and client representation for all respective transport, installation and construction phases of any given project.

Energy conversion technology has always been a main focus for researchers in order to meet the increasing demand as well as securing a clean, consistent and reliable energy supply. The constantly rising fuel price is another good reason to develop alternative systems such as

wind turbines, hydropower, photovoltaic systems and other renewable energy solutions. This book contains a collection of selected research works in the areas of electric energy generation, renewable energy sources, hybrid system, electromechanical energy conversion, electric machines, power electronic converters and inverters, energy storage, smart grid and traditional energy conversion systems. The book intends to provide academic and industry professionals working in the field of energy conversion and related applications with an update in energy conversion technology, particularly from the applied perspective.

These proceedings gather a selection of refereed papers presented at the 1st Vietnam Symposium on Advances in Offshore Engineering (VSOE 2018), held on 1–3 November 2018 in Hanoi, Vietnam. The contributions from researchers, practitioners, policymakers, and entrepreneurs address technological and policy changes intended to promote renewable energies, and to generate business opportunities in oil and gas and offshore renewable energy. With a special focus on energy and geotechnics, the book brings together the latest lessons learned in offshore engineering, technological innovations, cost-effective and safer foundations and structural solutions, environmental protection, hazards, vulnerability, and risk management. The book offers a valuable resource for all graduate students, researchers and industrial practitioners working in the fields of offshore engineering and renewable energies.

The coastal zone is the host to many human activities, which have significantly increased in the last decades. However, sea level rise and more frequent storm events severely affect beaches and coastal structures, with negative consequences and dramatic impacts on coastal communities. These aspects add to typical coastal problems, like flooding and beach erosion, which already leading to large economic losses and human fatalities. Modeling is thus fundamental for an exhaustive understanding of the nearshore region in the present and future environment. Innovative tools and technologies may help to better understand coastal processes in terms of hydrodynamics, sediment transport, bed morphology, and their interaction with coastal structures. This book collects several contributions focusing on nearshore dynamics, and span among several time and spatial scales using both physical and numerical approaches. The aim is to describe the most recent advances in coastal dynamics.

Design of Foundations for Offshore Wind TurbinesJohn Wiley & Sons

Wind Energy Engineering: A Handbook for Onshore and Offshore Wind Turbines is the most advanced, up-to-date and research-focused text on all aspects of wind energy engineering. Wind energy is pivotal in global electricity generation and for achieving future essential energy demands and targets. In this fast moving field this must-have edition starts with an in-depth look at the present state of wind integration and distribution worldwide, and continues with a high-level assessment of the advances in turbine technology and how the investment, planning, and economic infrastructure can support those innovations. Each chapter includes a research overview with a detailed analysis and new case studies looking at how recent research developments can be applied. Written by some of the most forward-thinking professionals in the field and giving a complete examination of one of the most promising and efficient sources of renewable energy, this book is an invaluable reference into this cross-disciplinary field for engineers. Contains analysis of the latest high-level research and explores real world application potential in relation to the developments Uses system international (SI) units and imperial units throughout to appeal to global engineers Offers new case studies from a world expert in the field Covers the latest research developments in this fast moving, vital subject

Wind energy is one of the most promising renewable energy nowadays. To collect better wind resources, more efforts are putting forward to offshore areas, and the reliability and stability of offshore wind turbines become critical topics. The cost of wind turbine foundation accounts as much as 35% of whole project, and the load patterns of offshore wind turbines are different from other offshore structures. Therefore, an efficient foundation type is required. Suction bucket foundation, a promising alternative for offshore wind turbine foundations, is introduced in this study. In the design of offshore suction bucket foundations, it is necessary to conduct a comprehensive study to understand their behaviors under variable load and soil conditions. However, few open literature described in-situ tests of offshore suction bucket foundations, and the accuracy of 1-g laboratory tests are limited. In this research. A series of centrifuge tests were performed to investigate the seismic and lateral behaviors of offshore suction bucket foundations under earthquake loads, lateral static loads and lateral cyclic loads in both sandy soil and clay. Original suction bucket foundations with three aspect ratios and improved suction bucket foundations with internal compartments were tested. The test results are presented and used to calibrate the theoretical calculations. The research is expected to provide insights into designs of suction bucket foundations for offshore wind turbines.

A COMPREHENSIVE REFERENCE TO THE MOST RECENT ADVANCEMENTS IN OFFSHORE WIND TECHNOLOGY Offshore Wind Energy Technology offers a reference based on the research material developed by the acclaimed Norwegian Research Centre for Offshore Wind Technology (NOWITECH) and material developed by the expert authors over the last 20 years. This comprehensive text covers critical topics such as wind energy conversion systems technology, control systems, grid connection and system integration, and novel structures including bottom-fixed and floating. The text also reviews the most current operation and maintenance strategies as well as technologies and design tools for novel offshore wind energy concepts. The text contains a wealth of mathematical derivations, tables, graphs, worked examples, and illustrative case studies. Authoritative and accessible, Offshore Wind Energy Technology: Contains coverage of electricity markets for offshore wind energy and then discusses the challenges posed by the cost and limited opportunities Discusses novel offshore wind turbine structures and floaters Features an analysis of the stochastic dynamics of offshore/marine structures Describes the logistics of planning, designing, building, and connecting an offshore wind farm Written for students and professionals in the field, Offshore Wind Energy Technology is a definitive resource that reviews all facets of offshore wind energy technology and grid connection.

This topical book describes the results of a large industry and government-funded research project aimed at developing design guidelines for novel foundations for offshore wind turbines, presenting current state-of-the-art solutions for offshore wind turbines.

This is a print on demand edition of a hard to find publication. Offshore wind power is poised to deliver an essential contribution to a clean, robust, and diversified U.S. energy portfolio. Capturing and using this large and inexhaustible resource has the potential to mitigate climate change, improve the environment, increase energy security, and stimulate the U.S. economy. The U.S. is now deliberating an energy policy that will have a powerful impact on the nation¿s energy and economic health for decades to come. This report provides a broad understanding of today¿s wind industry and the offshore resource, as well as the associated technology challenges, economics, permitting procedures, and potential risks and benefits. Charts and tables.

Wind power plants teaches the physical foundations of usage of Wind Power. It includes the areas like Construction of Wind Power Plants, Design, Development of Production Series, Control, and discusses the dynamic forces acting on the systems as well as the power conversion and its connection to the distribution system. The book is written for graduate

students, practitioners and inquisitive readers of any kind. It is based on lectures held at several universities. Its German version it already is the standard text book for courses on Wind Energy Engineering but serves also as reference for practising engineers.

This book provides an overview of floating offshore wind farms and focuses on the economic aspects of this renewable-energy technology. It presents economic maps demonstrating the main costs, and explores various important aspects of floating offshore wind farms. It examines topics including offshore wind turbines, floating offshore wind platforms, mooring and anchoring, as well as offshore electrical systems. It is a particularly useful resource in light of the fact that most water masses are deep and therefore not suitable for fixed offshore wind farms. A valuable reference work for students and researchers interested in naval and ocean engineering and economics, this book provides a new perspective on floating offshore wind farms, and makes a useful contribution to the existing literature.

This book is open access under a CC BY 4.0 license. This volume addresses the potential for combining large-scale marine aquaculture of macroalgae, molluscs, crustaceans, and finfish, with offshore structures, primarily those associated with energy production, such as wind turbines and oil-drilling platforms. The volume offers a comprehensive overview and includes chapters on policy, science, engineering, and economic aspects to make this concept a reality. The compilation of chapters authored by internationally recognized researchers across the globe addresses the theoretical and practical aspects of multi-use, and presents case studies of research, development, and demonstration-scale installations in the US and EU.

This study presents options to speed up the deployment of wind power, both onshore and offshore, until 2050. It builds on IRENA’s global roadmap to scale up renewables and meet climate goals.