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Downwind offshore wind turbines: Opportunities, trends and technical challenges

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ABSTRACT

In current offshore wind turbine designs, many are basic concepts using standard land-based wind turbines 'marinised' using a platform from the offshore oil and gas industry with additional anti-corrosion and structural stiffness. These projects are also focused on fixed offshore wind turbines at depths of less than 50 m. The design conservatism observed is present to avoid many changes to the proven technology on land-based wind turbines and offshore fixed foundations, to assure technical feasibility and economic viability in the short term. However, exportation of onshore technology directly to the offshore environment may not be entirely advantageous. There are opportunities in new designs or configurations, which can potentially lower cost of energy in a less restrictive offshore environment.

This paper aims to review the current offshore wind technology and discusses comprehensively some of the factors and opportunities in selecting a downwind configuration for offshore wind turbines. In addition, current industry, research and developmental trends for downwind offshore wind turbines are described. Various technical challenges and gaps foreseen for this design motivation are also highlighted in the paper.

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1. Introduction

For the majority of countries in the world, non-renewable energy sources such as coal, natural gas, oil and nuclear are used as the primary source of energy [1]. The burning of fossil fuels that result in massive amounts of carbon dioxide emissions have been widely accepted to cause adverse environmental effects such as global warming. A substantial redirection of energy policies is vital to reduce the harm and extend of climate change in the world [2]. While fossil fuels are subjected to price volatility due to high dependence on political and social-economic events across the world, various countries are in search for low-cost energy sources and technologies which will allow them to be more energy independent.

Renewable energy is a key pillar in low-carbon energy supply mix. With many strong driving forces, these renewable energy resources have generated huge amount of interest and shown the fastest growth among other energy sources [3]. With the support of global subsidies and cost reductions, renewables resources is expected to gain significant share of the world power generation [4].

For the past four decades, wind power is the leading source of renewable energy and has become potentially one of the major sources of energy of the 21st century [5]. On a percentage basis, wind energy has also been one of the world's fastest growing energy sources due to its reliability and cost-effectiveness [6]. One of the key reasons for the growth of wind energy is due to advantages in the economics and competitiveness compared to the other sources of energy [7].

The majority of the growth of wind energy was attributed to land-based wind power projects [8]. As such, favorable lands with good wind resource will be steadily taken up, a trend being observed in Europe [9]. In the United States, the majority of the land-based wind resources are located in areas with low population [10]. Like many other countries, a main challenge to future development of wind energy is the insufficient transmission-line capacity to highly populated areas (load centers) near the coast line [11].

Offshore wind energy is one of the key research and development directions in the wind energy sector [12]. Musial et al. [13] suggested that offshore wind energy has the potential to become a major source of energy in the United States. Some of the reasons explained by Musial et al. [13] and Shikha et al. [14] to site turbines offshore are: (1) location (could be near highly populated coastal loads where onshore wind energy is not available); (2) higher wind speeds; (3) lower turbulence; (4) reduced visual impact; (5) reduced noise impact.

2. Current offshore wind turbine technology

Most offshore wind projects are focused on fixed offshore wind turbines at depths of less than 50 m. This is expected due to the mature technology in fixed foundations [11], assurance in technical feasibility and economic viability [15]. Floating wind turbines can be used in deeper water and allow offshore wind turbines to be installed in more areas. It is also possible that the larger turbines may be transported, deployed and decommissioned at a lower cost [15,16].

Offshore environment is generally more challenging where foundations and floating platform need to account for turbine weight and height, the nature of the seabed, the depth of water, loads and dynamics of the system, and expected storm conditions [17].

Offshore wind turbine used commercially and developmental projects can generally be classified according to the type of support structures used. Each type of support structures has its advantages and disadvantages, and is selected based on numerous factors. The following sections provide an overview of the substructures associated with actual wind turbine/farm projects. From the projects presented below, all except for the SWAY prototype wind turbine employ the basic concepts of using standard land-based upwind wind turbines and 'marinised' using a support structure adapted from the offshore oil and gas industry with additional anti-corrosion and structural stiffness.

2.1. Fixed structures

In shallow water below 50 m in water depth, five main types of structures have been used, as shown in Fig. 1:

Monopile (Fig. 1a) – The monopile is the simplest and cheapest type of foundation that is used commonly in the North Sea. The structure is a steel or concrete tube driven into the seabed to a depth of 0–25 m [18]. The tower of the turbine is usually connected to the monopile with a transition piece. The monopile structure has been used in many major offshore wind projects, such as the London Array offshore wind farm [19], Horns Rev 1–2 [20,21], DanTysk offshore wind farm [22] and Anholt offshore wind farm [23].

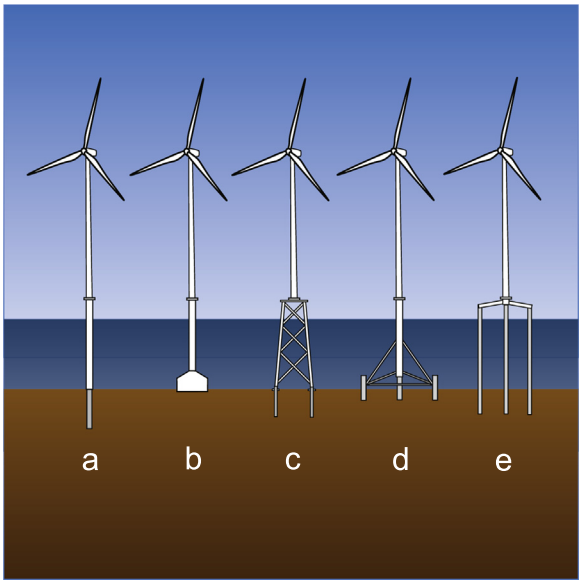

Fig. 1. Fixed structures for offshore wind turbines.