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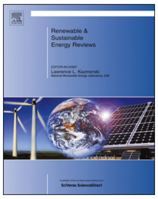

Off-shore wind farm development: Present status and challenges

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ABSTRACT

Offshore wind farm (OWF) is an emerging technology in the wind energy conversion system. These wind resources are abundant, stronger, and are more consistent in terms of their availability than land-based wind resources. As a matter of fact significantly higher energy production is achieved due to larger wind turbine ratings and stronger wind profiles.

This paper highlights the present scenario and challenges in development of offshore wind power. The challenges and opportunities that exist in the development stages of an offshore wind farm project, from exploration to erection and installation of wind turbines, construction of platforms and laying of sea cables, up to maintenance and de-commissioning, involving important technical aspects are addressed. An application of high voltage direct current (HVDC) transmission for integration of large scale offshore wind farm with onshore grid is attractive as compared to high voltage alternating current (HVAC) transmission system. To make the offshore wind farm feasible, reliable and secure, the different aspects in its planning, design and operation are also reviewed in this paper.

Contents

1. Introduction

Due to depletion of the fossil fuels, leading to acute scarcity of energy production from the conventional source, there is an upsurge in utilization of the non-conventional energy resources like wind,

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solar, biomass etc. Offshore wind farm (OWF) is expected to become a major source of energy globally due to its several advantages. The major utilization of OWF is remarkably visible in European countries and some parts of the United States. The generation planning for next decade i.e., up to 2020 is on a full swing supplemented by numerous statistical data available from different agencies. The challenges in its installation and reliable operation are significant. The shallow water makes a major obstruction as it effects reinforce structure because the water is not remarkably deep, its basement structure may not be solid, which makes a major hindrance for initial installation, etc.

In the past, the negative impacts have developed a great deal of opposition to the first OWF proposals in the U.S. and in turn delayed its development. In [1] the authors have investigated the positive and negative impacts of offshore wind energy. In this context, the cost factor and benefits of offshore wind relative to onshore wind power and the conventional electricity production is discussed.

As of today's status, the wind power generation is considered to have huge potential for its growth. Europe continent is the leader in offshore wind energy having its first OWF installed in Denmark in 1991. In the late 1990s single wind turbine (WT) with power ratings less than hundreds of kilowatts were installed but today, OWFs are planned with capacities even above 1000 MW. Thus, it may be said that OWF have generation capacities comparable to existing conventional power plants.

The bar chart given in Fig. 1 represents the world wide wind energy installation at present and its estimated future growth [2]. From the bar chart it is reflected that there is a remarkable augmentation of OWF installation up to the year 2020. However, this growth in estimated generation is less than onshore wind farm. Hence it can be concluded that the road map of OWF is brighter and in the global scenario, its implementation as a major energy production will definitely become predominant in future. A comparative trend in growth of onshore from year 1992 to 2004 has been compared to estimated growth of OWF in Fig. 2. This suggests an increased potential for growth for OWF in years to follow.

The wind energy conversion in to electric form is carried out using either fixed speed or variable speed generators. In order to achieve maximum extraction of available wind power, variable speed operation is preferred over the fixed speed machines. Variable speed machine maintains steady output under varying wind conditions. The various AC machines like, doubly-fed induction generators (DFIGs), wound rotor induction generators, synchronous generators (SGs) or permanent magnet synchronous generators are used with variable speed wind turbines. However, among these, DFIGs are the most widely used due to its overall low cost, its modular, compact and standardized construction. Though, this machine has a complex drive train and requires effective pitch control [3], its advantages outweigh the disadvantages and have become a viable option. These machines are basically wound rotor induction generator having its rotor connected to grid through a back-to-back converter. The converter is one-third of the machine rating. Most of the OWFs use 20 kV or 33 kV voltage level for interconnection of individual wind turbines and then stepped up to 150 kV level to feed power through one or more cables to the grid. Another transformer may be needed for connection into 400 kV grids.

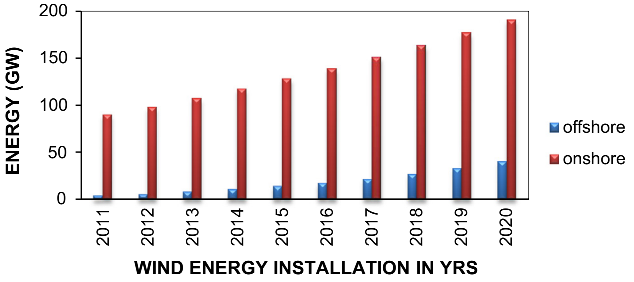
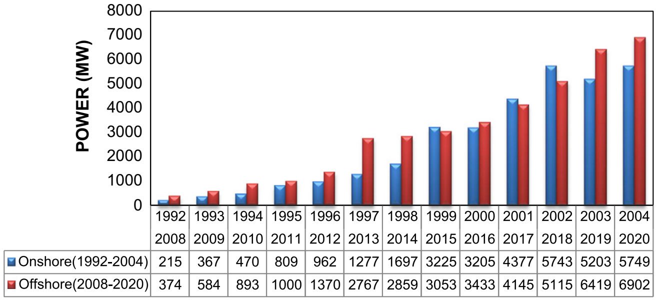


Fig. 1. Wind energy installations: 2011–2020(GW).



	1992 2008	1993 2009	1994 2010	1995 2011	1996 2012	1997 2013	1998 2014	1999 2015	2000 2016	2001 2017	2002 2018	2003 2019	2004 2020
🟦 Onshore(1992-2004)	215	367	470	809	962	1277	1697	3225	3205	4377	5743	5203	5749
🟥 Offshore(2008-2020)	374	584	893	1000	1370	2767	2859	3053	3433	4145	5115	6419	6902

Fig. 2. Onshore historical growth 1994–2004 compared to EWEA'S offshore projection 2010–2020 [].
Source: EWEA 2011

DC system technologies are beneficial for large scale integration of wind energy system which reduces cost and minimum grid impact as the bulk power is concentrated at single point of entry. For increased level of wind farm penetration, grid connection codes have constituted new challenges to wind farm control, design, operation and development. Thus we have to place significantly large structures of transmission and distribution system technology at offshore locations. Large wind farms that are composed of multi-megawatt wind turbines for an aggregate power potential have generally hundreds of turbines or even more. The interconnection of these units represents a technical challenge due to its location and stochastic nature of power produced. All OWFs operational today, are radially connected to the onshore electric grid through use of high voltage alternating current or high voltage direct current submarine cables. As HVAC subsea transmission schemes has limitation to the transmission distance, high power losses and resonance problems, HVDC transmission schemes are preferred. Due to the predominant capacitance effect of these AC cables, a large distance and amount of transmitted power is technically not feasible. The most economic solution for the connection of relatively large OWFs (500 MW and above) at a distance greater than 50 km, lies with the use of a HVDC link. This is advantageous against the undesirable effects of capacitance in submarine cables, and the corresponding high reactive currents, with the use of HVAC transmission lines.

The power through HVDC link is possible to vary the voltage of the offshore AC network in order to (i) avoid use of transformer tap changers, (ii) avoid use of a static compensator (STATCOM) or synchronous compensator and (iii) use an uncontrolled rectifier instead of a controlled one. It is also economically advantageous as diodes are cheaper, do not require gate drivers and have low losses. In addition, absence of STATCOM and transformer-tap changer increases the system reliability. Currently, two converter technologies are commonly used for marine HVDC links, namely voltage source converters (VSCs) or line commutated converters (LCCs). VSCs are based on IGBTs, GTOs or IGCTs, whereas LCCs are based on thyristors. LCCs were developed about 50 years back and LCC-HVDC shows remarkable advantages in terms of power rating and losses. The LCC based HVDC integrated with a large offshore DFIGs-based wind farms connected to the main onshore network is controlled by STATCOM [4].

Due to an increased penetration level of wind farm, its impact on operation of power system components exaggerates. Consequently, this has lead to active research works on various issues; planning and design, security, protection, stability, reliability and power quality.

A review of the important modeling techniques employed for developing flexible AC transmission system (FACTS) controllers is given in [5]. The authors also examine the role of HVDC-light transmission in exploiting the offshore wind energy resources.