Offshore Wind farm layout optimization – State of the art

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ABSTRACT

Offshore Wind is one of the most promising renewable energy sources but the cost is still too high to be competitive. Optimizing the layout of a wind farm may help to improve the competitiveness, but it presents a significant engineering challenge.

This paper presents the state of the art of offshore wind farm layout and identifies the main criteria used for its optimization with respect to a number of parameters such as the cost of energy and annual energy production. Used methodologies in farm design as well as key aspects of a wind farm that are subject to optimization will be analyzed. Available commercial software for wind farm design will also be presented and characterized and their limitations identified. The paper concludes with suggestion for further investigation.

KEY WORDS: offshore; wind; energy; layout; optimization; algorithm; cost.

INTRODUCTION

Wind energy has been one of the main and fastest growing sources of renewable energy and has contributed significantly for the decarbonization of the electric sector. Onshore wind has been the main contributor to this growth with a yearly average growth rate of 15.6% between 1996 and 2011 and with more than 96 GW installed just in Europe (Wilkes, Moccia and Dragan, 2012).

First offshore wind farms were installed in the late 90’s in Northern Europe in shallow waters (5 to 10 m deep) and were using in monopiles. This type of solution is now commercial and represents a share of 9.2% of the total installed capacity (Wilkes, Moccia and Dragan, 2012). More recent deployments show a trend to move further away from the coast and into deeper waters (up to 35 m). Although offshore wind is more complex and costly than onshore wind, both in deployment and maintenance, significant higher energy yields are expected due to the higher intensity and persistency of winds further offshore. The goal is to make offshore wind competitive with other alternative energy production technologies, including conventional technologies, i.e. achieve a Cost of Energy (CoE) lower than 100 €/MWh. Therefore, it is important to understand the offshore wind energy cost structure in order to control it and make a competitive business case.

During the last decade significant effort was applied in understanding onshore wind and maximizing energy extraction from wind. In what concerns farm design, most of the effort was applied in micro-sitting the wind turbines and in characterizing how the topology of the terrain interacts with the wind and its impact on the turbines performance. Therefore, in most of the cases the layout optimization of such wind farms only considers maximizing the Annual Energy Production (AEP) (Shengping and Li 2010). The same optimization criteria was used for the early years of offshore wind, where the wake effect was the main effect that was taken into account in the definition of an offshore wind farm layout (Rivas, 2007).

As the wind farms started to be installed in lower wind sites or going offshore further away from the coast or into deeper waters, other concerns were raised. The complexity of installing a wind farm increased significantly so maximizing the AEP was not enough to make a competitive business case. The wind farm layout is a key element in the profitability of a project, so more complex optimization approaches were developed.

This paper will first characterize the offshore wind farm main cost drivers and identify what impacts the CoE. The next section introduces the aspects and components of a wind farm that affect its cost and that can be subjected to optimization. Several optimization algorithms are presented. The wind farm layout optimization’s state of the art is reviewed and the commercially available software is identified and characterized. Finally a set of conclusions are presented.

OFFSHORE WIND FARMS COSTS

Offshore wind farms started to be developed in late 90’s being Middelgrunden in Denmark one of the pioneer projects in this sector. The first wind farms were installed in shallow waters (less than 20 meters water depths) and relatively close to the coast.