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Potential applications for small scale wave energy installations

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ABSTRACT

The paper provides an overview of linear generator development and testing experience of three different prototype solutions applicable for small-scale wave energy converters. The research was focused on wave power utilization in the Baltic Sea – basin of relatively low wave energy conditions. Developed technical solutions have been tested for their applicability and efficiency in small scale pilot cases. The presented concepts are based on developed linear generator. The unique arrangement of the pairs of permanent magnets and ferromagnetic cores between them was used in order to achieve better inductive properties of a magnetic field and as result, fewer materials were used and more electric power was generated. The developed engine was assessed against three concepts: (1) engine embedded in the stand-alone device in an almost water isolated floating carrier; (2) attached to a Single Point Mooring Buoy providing an additional source of energy for marine navigation signs; and (3) attached to the sea-wards looking pier in order to provide an illumination. Newly developed technical concept, such as a small-scale, versatile, low-cost and high capacity linear generator, and proposed installation solutions may open opportunities for wave energy utilization also in the regions of low wave energy such as the Baltic Sea.

Contents

1. Introduction

The EU Parliament has adopted a report which calls for an increase in electricity generated from renewable energy sources from 12.2% in 2002 to 20% by 2020 (COM (2004) 366, the Share of Renewable Energy in the EU, 29/09/05). The Directive 2009/28/EC on renewable energy sets ambitious targets for all Member States, to reach a 20% share of energy from renewable sources by 2020. To meet this target there has been a significant growth and interest in offshore renewable energy technologies and sources, such as offshore wind, wave and tidal.

Wave power, along with other marine renewable energy-generating sources like tides and currents, is underestimated considering its

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advantageous physical properties and predictability [7]. Waves are a renewable energy source with high power density and relatively high utilization factor. The floating devices usually have low visual and presumed low environmental impact if compared to other renewable sources [13]. Waves provide a predictable energy source that is relatively easily tapped. Although still mostly at experimental stage, wave energy could soon compete with other renewable energy sources. The wave energy related issues form the most heavily researched and funded sector in the ocean power industry. This source of renewable energy is able serving up to 10% of global demand in grid power [27].

The current study is inspired by the analysis of wave regimes in the Baltic Sea [10,26,7] and includes technical aspects of existing installations of wave energy devices [4], some socio-economic and environmental considerations related to the newly developing sector. Study is focused on the pilot studies carried out in Lithuania. Those include development of an innovative linear generator and its testing in various applications at the near-shore of the south-eastern (SE) part of the Baltic Sea.

The Baltic Sea is recognized as semi-enclosed, almost tide-less basin. This is probably one of the reasons why the hydrodynamic potential of the Baltic Sea have not received proper attention in terms of energy production in the past. Consequently, water basins where the height of waves and/or the power of the tides are considerably bigger than those in the Baltic Sea can be recognized to have sufficient revenue of the investments. Still, investments into the development and testing of concepts and prototypes for extraction of the tidal and wave energy are gradually increasing. There are studies made to assess the wave energy potential in other low energy basins, such as the Mediterranean [30,15] and the Black Sea [1,20]. Newly developed concepts aim to minimize the costs of potential investments and maximize the efficiency of the developed equipment in order to be applicable for the Baltic Sea conditions as well as other low wave energy basins.

2. Theory

2.1. Environmental conditions

The Baltic Sea is the world's largest brackish water sea (surface area is more than 393,000 km^2), being comparatively shallow with an average depth of only ~54 m [12] and with a maximum depth of ~459 m. Waves in the Baltic Sea are basically induced by the local wind and the proportion of remote swell is usually minor. In winters, stormy winds are quite frequently observed. Extensive relatively shallow areas in this basin may host extremely complex wave fields and unexpectedly high waves, formed in the process of wave refraction and optional wave energy concentration in some areas [28,25]. Storm waves are relatively steep and short, high waves are rather seldom. Significant wave heights hardly exceed 8 – 8.5 m [24,26]. The map of wave height (Fig. 1) shows significant asymmetry of mean wave height in the largest sub-basins – the Baltic Proper and the Bothnian Sea. The waves in the eastern part of the Bothnian Sea are clearly higher (> 0.8 m on average) than those in the western area. The average waves are the highest in south of Gotland and east of Öland, and in the Arkona basin where the average wave height exceeds 0.9 m. In the northern part of Baltic Proper waves are the highest along the coasts of Estonia and Latvia. The wave heights are slightly lower (< 0.7 m on average) along the coasts of Lithuania, Kaliningrad district and north-eastern Poland. The map (Fig. 1) reveals that the open part of the Bothnian Sea is also attractive as having relatively good wave

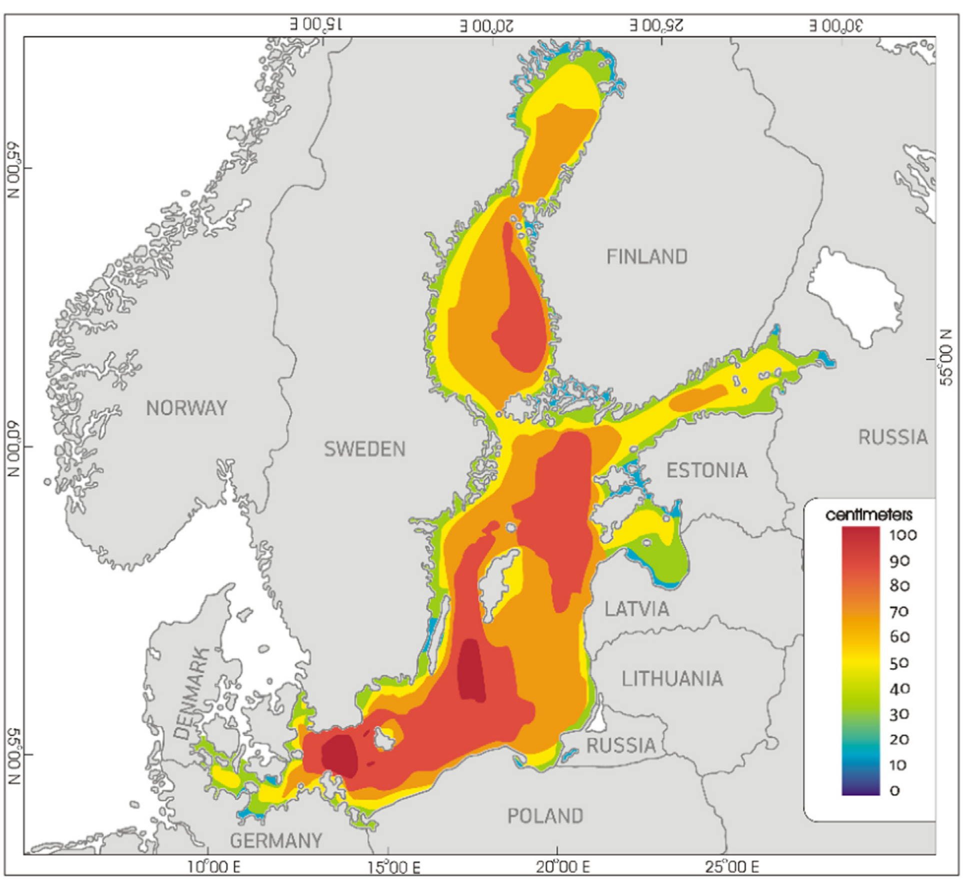

Fig. 1. Mean wave height (cm) in the Baltic Sea (for period 1970–2007; after [19]).