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Offshore hydrogen production from wave energy

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ABSTRACT

The aim of this paper is to present and evaluate a proposal for designing an off-grid offshore electrolysis plant powered by wave energy. This plant includes PEM electrolyzers, a Reverse Osmosis system to produce water with adequate conductivity, a compression unit to store the hydrogen for transport, and batteries for temporary storage of electricity for short-time balances. First, the systems that compose the proposed plant are justified and described. Then a proposal for sizing these subsystems is given, based on using buoy-measured data at the expected location and simple mathematical models of the different sections of the plant. Finally the performance of the plant in a specific location is tested in detailed by using measured data, studying the influence of sizing on the expected performance.

1. Introduction

This paper refers to a renewable energy offshore plant to produce hydrogen currently under development. It is well known that hydrogen is a clean energy carrier independent of energy sources [1]. The full benefits of hydrogen will be obtained when is produced from renewable energy sources. Different renewable energy sources have already been studied for electrolyzation, such as wind [2,3] and solar energy [4,5]; the feasibility of these sources to produce hydrogen has been demonstrated, with the main drawback the variability of these sources (see, for example [5], for a detailed feasibility and economical study), and the significant cost of solar hydrogen [6].

There are some published works on using reverse osmosis to obtain hydrogen from seawater, involving wave energy for generating the energy for the process [7,8]. There are even patents available that take into account this idea [9,10].

This paper concentrates on offshore systems: the source considered in this work is wave energy as wave converters provide lower variability in the energy production in comparison with other sources [11]. Offshore power links are known to be significantly expensive [12], so the system is here assumed to be fully isolated from the grid: it is parallel to the grid independent wind-hydrogen generation presented in [6]. Thus, power consumption adapts to power production by connecting or disconnecting sections of the electrolyzation plant (following a Smart Grid approach for the microgrid in the plant), and using a temporary storage of electricity for short-time balances and increase of autonomy (that is a relevant issue in offshore installations). Automatic cleanings and maintenance operations are scheduled in the sections that are temporarily disconnected, to improve overall efficiency. Compared with previous proposals [8–10], this paper concentrates on using commercially available components that are already tested in the marine environment. Special

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attention is given to the modeling for sizing of the components, the production of low-conductivity water for the electrolysis and the control system.

In summary, the system presented here is composed of a primary energy source, namely wave energy, which provides electricity in order to produce hydrogen using PEM electrolyzers. Water for these electrolyzers is obtained from seawater using membrane technologies based on Reverse Osmosis (RO [13],). A temporary storage system, consisting of a set of batteries for balancing production and demand is also installed. The hydrogen is then transported to the final users by ships (barges), after compression. It has been previously shown ([14]) that Energy Management Systems are the important components in these off-grid electrolyzation facilities, to improve efficiency of the process under variable production. A simple strategy is proposed here, to connect/disconnect components, depending on the amount of energy available, the state of charge of the batteries, and the amounts of water available for the electrolyzers and the desalination system.

The process diagram in Fig. 1 presents the four main blocks of our proposal: the wave converters, the Reverse Osmosis plant, the electrolysis unit and the compression unit. After the introduction, the proposed components are described in section 2, together with the proposed sizing methodology, and some mathematical models that can be used for this sizing. In section 3, results and discussion are proposed. Finally, some conclusions are provided in section 4.

2. Material and methods

2.1. Description of components

2.1.1. Wave converters

The number of companies that provide devices capable of exploiting wave energy is increasing every day. The output energy of a mechanism is basically determined by the system characteristics and the wave weather in the area [15].

We assume here the use of a wave converter multibody floating WEC, for offshore installations: the energy is extracted by the relative motion of different parts of the structure. The main advantage that these devices present is that, in deep water (>40 m), there is a greater energy potential because the waves have not yet experienced losses.

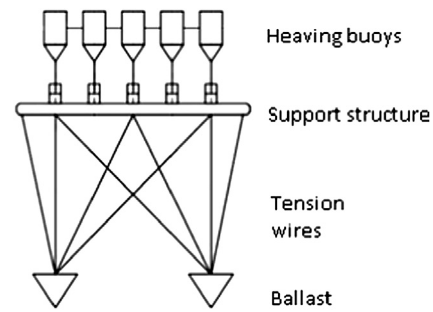

Fig. 2 – Scheme of the WEC.

Fig. 2 depicts the Wave Converter used in this study: it is composed of a common submerged reference structure, formed by a series of ballasts baskets, and connected through tension wires. The total buoyancy force from the buoys is balanced by ballasts baskets. The buoys are connected to the submerged structure via hydraulic Power Take-Off (PTO) systems, which converts the mechanical energy into hydraulic energy, which is later converted in a turbine into electrical energy.

One of the key points in the structural design and energy extraction capacity of the device is the response to different periods and wave heights (Fig. 3).

The devices have a maximum range of operation: The energy that can be used by a device is limited to a maximum wave height and a minimum wave period.

2.1.2. Electrolysis

Electrolyzation is a mature, market-available technique that can operate intermittently, producing large volumes of hydrogen without greenhouse gases emissions, as long as the electricity is provided by renewable sources [16].

In this proposal we focus on PEM electrolyzers, as they have advantages in terms of safety when compared with

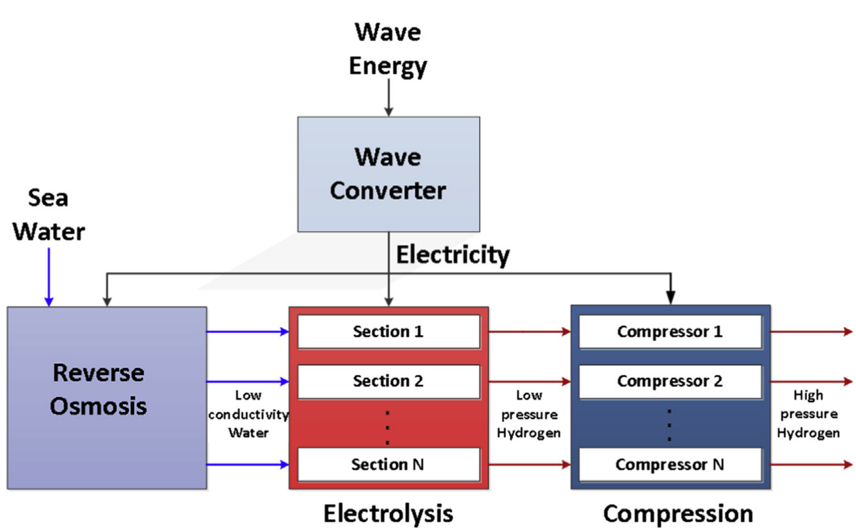

Fig. 1 – Process diagram.