Energy assessment of a wave energy converter in Ustica island. A case study

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***Abstract*— In the global energy scenario entered the sea generation for a few years ago. This includes the exploitation of sea and ocean masses for energy production. Governments are focusing on these technologies by encouraging incentives and action plans. This paper analyzes the current situation of wave technologies and describes a case study of power generation. A wave energy converter (WEC) was modeled located on the coast of Ustica, a small island located in Sicily, Italy. The hypothesized model and electrical energy producibility will be described.**

Keywords—wave energy converter, sea wave, Mediterranean Sea, renewable energy

I. Introduction

Unlike the other established renewable sources, photovoltaic and wind characterized by a physical phenomenon that can in fact be exploited by a single technological system for conversion into electricity, the tidal source is composed of six distinct sources, each with a different origin and requiring different technologies for conversion. So, the present paper aims to analyze non-"conventional" renewable sources for power generation. In particular, the use of wave motion as an energy source was considered developing and analyzing the producibility of a generator. Strategies put in place by the EU to combat climate change and promote increasingly efficient energy use are very timely [1], [2].

In Italy, both the National Energy Strategy (SEN) and the National Integrated Energy and Climate Plan (PNIEC) have been considered, as well as the various incentives for energy from non-photovoltaic electric renewable sources [3], [4], [5]. Italy has made great progress in renewable sector, and having already achieved the main targets set in the 20-20-20 package in 2015, it issued the National Energy Strategy [6], [7].

Wave energy conversion is related to the interaction between wind and sea [8], [9], [10]. Convective motions in the atmosphere are induced by temperature gradients caused by non-uniform heating of the globe. The Earth gives up heat received from the Sun to the atmosphere, but not uniformly. In areas where less heat is given up, atmospheric gas pressure increases, due to higher air density, while where more heat is given up, the air becomes warm, thus less dense, and atmospheric pressure decreases locally. Thus, zones of high pressure and zones of low pressure are formed, which are also influenced by the rotation of the earth. Air masses move from a high-pressure zone to a low pressure zone because they are subjected to a force that is called the pressure gradient force. This shift generates the wind. The wind generates waves, motions, rises and subsequent falls on the sea surface that are a direct function of the generating cause. When the wind blows over the sea surface some of the kinetic energy of the moving air mass is transferred to the sea, and thus there is this exchange of energy at the surface. Once created, wind-induced waves can travel thousands of miles with small energy losses. The following fig. 1 shows this interaction between wind and sea.

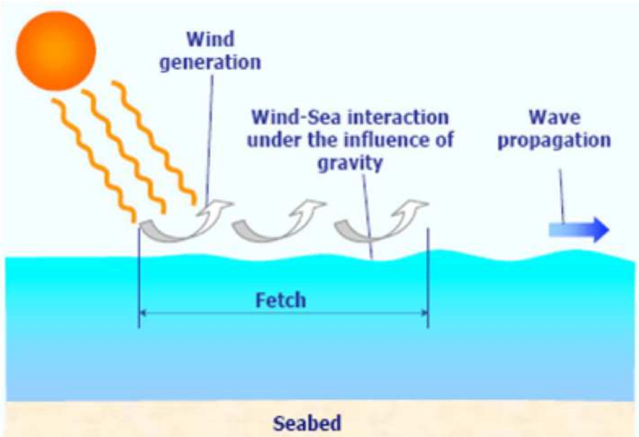

Fig. 1. Sea wave generation

As the wave approaches the coast, the energy intensity decreases due to the interaction with the coast and the seabed. Some of the kinetic energy of these moving masses dissipates by impact on the seabed rather than on the coast. The elements that determine variations in both energy and geometry of a wave are: wind speed, the greater the wind the greater the size of the wave; length of time for which the wind laps the sea surface; the Fetch i.e. the length of the stretch of sea over which a wind blows or has blown such that the wave is generated [11], [12].

The paper will be divided into sections: case study, where the location and the condition sea wave are described; results and discussion, where the results of modelling are shown; and then conclusion.

II. CASE STUDY

A. Location

The island of Ustica is located in the southern Mediterranean Sea, Sicily, about 36 nautical miles from the Palermo coast about 65 km and has an area of 8.5 km^2. The island turns out to be the tip of a huge submerged volcanic edifice that is part of an alignment of submarine craters of a fault located over 1,000 m deep. The fig. 2 shows the island distance from the mainland.

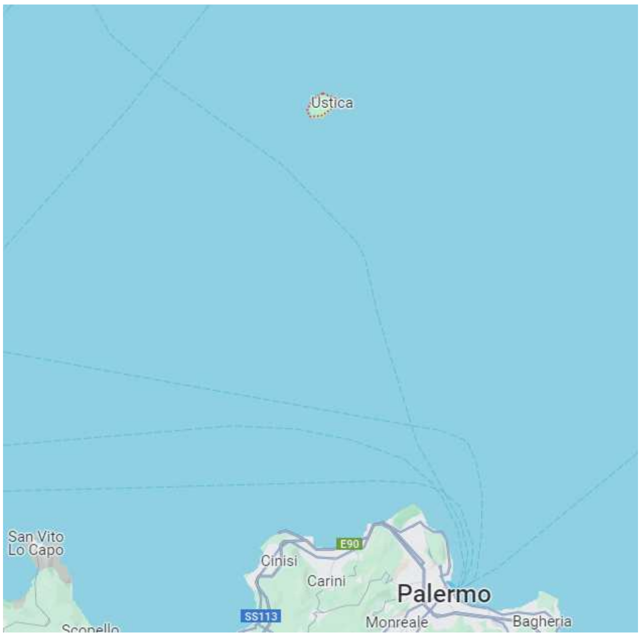

Fig. 2. Ustica location in Mediterranean Sea

The Ustica Marine Protected Area, with an area of about 16,000 hectares of sea, is divided into three zones:

- A zone A, of integral reserve. In this area, navigation, mooring and parking of all types of boats is prohibited, and fishing and any other action that may cause disturbance or alter the natural characteristics of the environment is prohibited. Bathing and snorkeling are permitted.
- A general reserve area B, which includes the northwestern side of the island. The taking of any plant or animal life is prohibited in this area but recreational boating is permitted.
- A partial reserve zone C, which includes the southeastern slope. Boating and docking are allowed in this zone. Professional fishing is allowed only by local fishermen with a permit

B. Sea wave characteristics

To characterize the sea state of the waters surrounding the island of Ustica, a database using the period from 03/28/2002 to 03/11/2014 as the time interval was considered [13], [14]. For the creation of this database, measurements taken in the 30-minute interval from the Capo Gallo station were exploited since it appears to be geographically the closest to Ustica.

The values carried out from the national sea wave network are the wave period, fig. 3, the significant wave height, fig 4, and the mean direction of the wave, fig. 5 [15], [16].

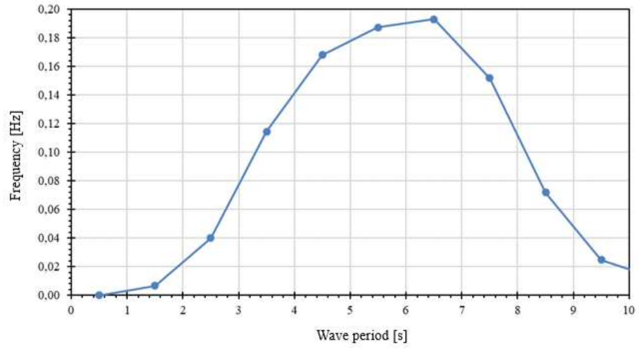

Fig. 3. Wave period for the

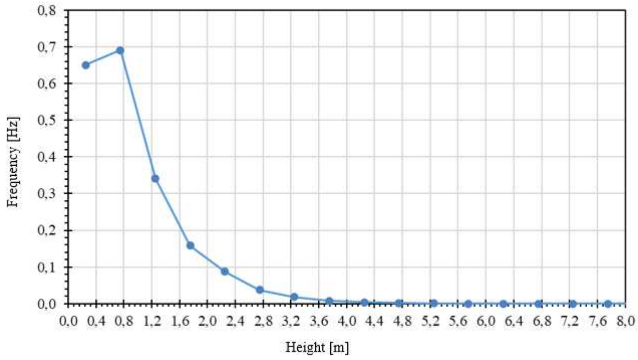

Fig. 4. Significant wave height

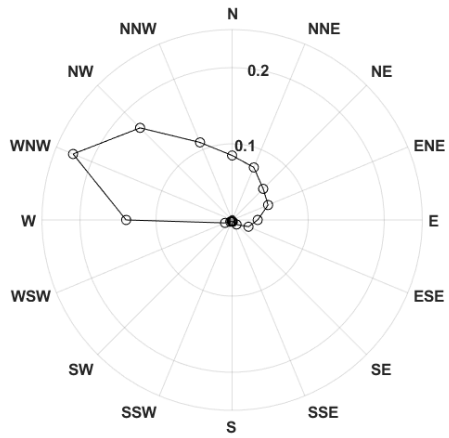

Fig. 5. Mean wave direction

C. Wave energy converter

The case study is based on the analysis of a device consisting of a floating buoy having the cylindrical hemisphere geometric configuration [17], [18]. The wave motion is captured by the buoy connected by a rod to a Mechanical motion converter that allows the alternating motion to be transformed into rotary motion. As shown in Fig. 6, the system is on shore installable in a harbor dock.

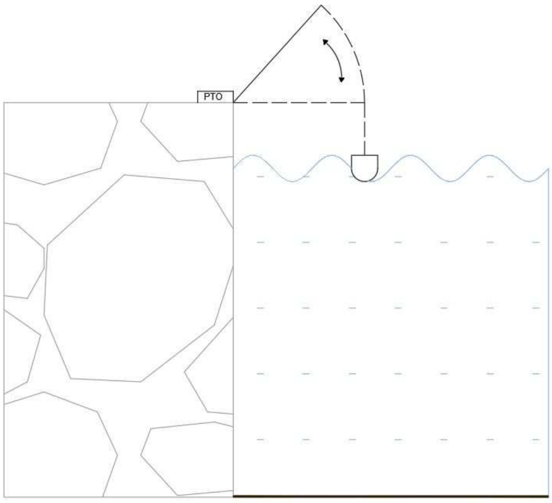

Fig. 6. Wave energy converter configuration

The geometry and model of the device were created using Ansys' AQWA tool. The software provides an engineering toolset for studying the effects of environmental loads on fixed or floating structures. First step of the examination was the creation of the buoy using Design Modeler. The capturing buoy consists of a 2 m high cylinder and a hemisphere, at the bottom, with a diameter of 4 m.

A "Fixed Point Hinge" was inserted at a horizontal distance of 10 m from the device and 5 m above sea level to simulate the connecting hinge between the rod and the dock. The connection between the hinge and the structure was achieved by introducing a constraint, "joint," of the "Hinged" type. This provides a degree of rotational freedom along one axis, depending on the direction of the waves.

For the correct representation of the device, it is necessary to derive the weight of the buoy. This is determined from Archimedes' Principle. Buoyancy is verified if the buoyancy acting on the body must equal its weight force according to the following equations:

$$S_A = V_w \rho_w g \tag{1}$$

$$F_P = V_c \rho_c g \tag{2}$$

Equalizing the two equations:

$$V_w \rho_w g = V_c \rho_c g \tag{3}$$

$$V_w \rho_w = M \tag{4}$$

Where:

S_a is the push of Archimede, V_w is the eater volume moved, ρ_w is the sea water density (1025 kg/m^3), g is the gravity acceleration, V_c is the body volume, ρ_c is the body density, and then M is the body mass. From the mass body value, it is necessary to calculate the inertia moment on the three principal axis, following the (5).

$$I_{tot} = I_{hemisphere} I_{cilinder} \tag{5}$$

The following table 1 shown the geometric parameters used in modelled case study.

TABLE I. GEOMETRIC PARAMETERS

V_w	25.13 m^3
V_c	41.88 m^3
ρ_c	410 m^3
M	1717 kg
I_{xx}	43936.92 kg m^2
I_{yy}	43936.92 kg m^2
I_{zz}	50377.18 kg m^2

III. RESULTS AND DISCUSSION

The results of simulations, carried out with the aim of estimating the energy producibility of the device, are shown below. See figure 7.

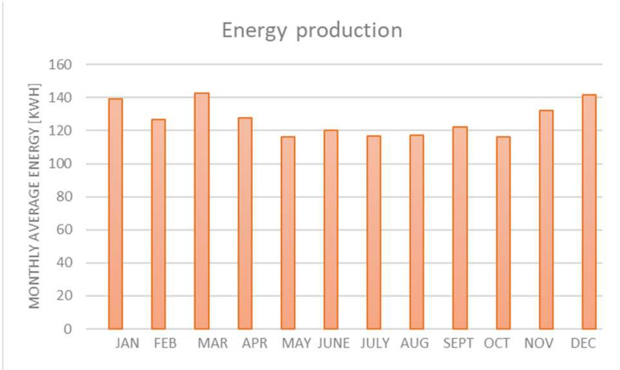

Fig. 7. WEC energy production

The annual energy production is around 1500 kWh. This value is greatly influenced by low seabed deep near the coastline of Ustica, 25 m deep.

The sea conditions implemented in the software simulations consider the variation of significant height from 0.5 m to 4 m and peak period variation from 1 s to 10 s. The maximum power extracted of 2.5 kW is related to 1.75 m height and 5 s period. In general, the maximum values of power are related to the range 1.25-1.75 m and 4-5 s.

IV. CONCLUSION

The exploitation of Ocean Energy has a number of characteristics such as: low visual impact (depending on the plant type), good energy density, high prediction and replicability of the phenomenon, with potential efficiency depending on the availability of the resource and the site of installation. Since it is a universally available source, if properly exploited it can mitigate the energy supply and security problems of various countries. In fact, by properly realizing energy farms capable of being able to exploit not only the phenomena connected to the sea but also those connected to the wind source, in offshore configurations, one could easily succeed in powering the small islands present in the national territory. For a little island as Ustica producing 1500 kWh from a renewable power plant could help the green energy road toward the abandonment of fossil systems.

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