Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 125 (2017) 415–424

Energy Procedia

www.elsevier.com/locate/procedia

European Geosciences Union General Assembly 2017, EGU
Division Energy, Resources & Environment, ERE

Harnessing wind and wave resources for a Hybrid Renewable Energy System in remote islands: a combined stochastic and deterministic approach

Evangelos Moschos[a,*], Georgia Manou[b], Panayiotis Dimitriadis[b], Vasileios Afentoulis[a], Demetris Koutsoyiannis[a], Vasiliki K. Tsoukala[b]

[a] *Laboratory of Harbour Works, Department ofWater Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, Iroon Polytechniou 5, 15780 Athens, Greece.*

[b] *Laboratory of Hydrology and Water Resources Utilization, Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, Iroon Polytechniou 5, 15780 Athens, Greece.*

Abstract

Wind and wave resources enclose an important portion of the planet's energy potential. While wind energy has been effectively harnessed through the last decades to substitute other forms of energy production, the utilization of the synergy between wind and wave resource has not yet been adequately investigated. Such a hybrid energy system could prove efficient in covering the needs of non-connected remote islands. A combined deterministic and stochastic methodology is presented in a case study of a remote Aegean island, by assessing a 100-year climate scenario incorporating uncertainty parameters and exploring the possibilities of fully covering its energy demands.

Peer-review under responsibility of the scientific committee of the European Geosciences Union (EGU) General Assembly 2017 – Division Energy, Resources and the Environment (ERE).

Keywords: renewable energy; wind energy ; wave energy ; HRES ; pumped storage; stochastic modeling ; numerical modeling ;

1. Introduction

Remote island residents do not enjoy the privilege of connection to the main electrical grid, that inhabitants of cities do. This creates significant problems for the most cases, where power is generated from oil-fueled plants, from

* Corresponding author. Tel.: +30 695 662 7248.
E-mail address: cv12050@mail.ntua.gr

1876-6102
Peer-review under responsibility of the scientific committee of the European Geosciences Union (EGU) General Assembly 2017 – Division Energy, Resources and the Environment (ERE).
10.1016/j.egypro.2017.08.084

dependency to oil market and prices [1], to inability to cover energy demand peaks, if the stored fuel is not enough. Hybrid Renewable Energy Systems (HRES) have been planned or installed in various locations. Such systems provide a sustainable alternative to wasteful oil-based energy production and carbon emissions, as well as self-sufficiency of the local communities [2]. Combined wind and wave energy utilization is examined here, in a HRES model suitable for non-connected, remote islands, with high availability of these resources. While wind energy technology is in commercial stage, marine/wave energy technology is currently in an early stage, from research to pre-demonstration on full scale. A wide variety of Wave Energy Converters (WECs) exist today; each technology uses different solutions to absorb energy from waves and can be applied depending on the water depth and on the location [3].

The case of the Aegean Sea belongs to the low-energy areas of Europe, thus wave energy converters have not been developed, while at the same time the large wind potential has not been fully harnessed. Nevertheless, several studies have shown the potential of both WEC installation and combined wind and wave resource utilization in the area of the Aegean Sea. Lavidas and Venugopal [4] created a 35-year wave energy atlas of the Aegean, on which they tested the energy production and performance of different WEC technologies. Furthermore, Friedrich and Lavidas [5] tested a combined HRES system consisting of a wind turbine, a WEC and a diesel generator at the island of Astypalaia, which is also examined in this study, evaluating the assets of combined wind and wave resource management. Finally, Ioannou et al. [6] simulated an HRES system in Donoussa, another remote Aegean island, consisting of a wind turbine and an overtopping WEC, providing a sustainable system with fully autonomy from the grid.

The selected case study area is Astypalaia, a Greek island in the south-eastern Aegean Sea. The island has about 1,300 inhabitants and it extends in an area of 96.9 km^2. Astypalaia has more than 20,000 visitors per year, creating high energy demand in the summer period. Today the electric energy demand is covered by an oil-fuelled thermal station, as the island is not connected to the energy distribution grid of the mainland and there are no renewable energy installations in the area. According to records from 2014 to 2015, the island's mean annual demand was 6,250 MWh. The peak hourly demand was 2.2 MWh (occurred on 14/08/2015 at 21:00) and the minimum was 0.23 MWh [7,8].

2. Modeling of wave climate

2.1 Wind and wave historical data

Measurements of wind and wave resources exist only in a few locations of the Aegean Sea. For the examined island, wind and wave data are unavailable on-spot, due to its remote location. For this reason, past wind and wave climate in the surrounding area of the island needs to be modeled and reconstructed. The historical data are then used as input in a numerical model to simulate a 7-year scenario for the years 2005 until 2011, in order to obtain time-series of wind and wave resources in the position of installation of the HRES. Wave data are obtained through the HCMR's (Hellenic Center for Marine Research) Poseidon buoy network [9]. The POSEIDON system is a real-time monitoring and forecasting system for the marine environmental conditions in the Aegean Sea. The Santorini and Mykonos buoys are picked out, being the most proximate to the location of Astypalaia; their location can be seen in Figure 1(a). For the operation of the numerical model, the parameters of Significant Wave Height, Spectral Peak Period, Wave Direction, as well as the Wave Directional Spreading are needed. The Poseidon buoys record, among others, these parameters on a 3-hourly basis. The short data availability as well as the big gaps in the measured time series of the buoys, create a limit in the available measured time period. Thus, time-series for the period between 2005-2011, in which consistent measurements are available, are isolated and the small gaps that exist in this period are filled through a high order auto-regressive model. Hence, the 3-hourly time series is obtained, which is used as input for the spectral wave model. For the same time period (2005-2011) reconstructed wind data is obtained through the ERA-Interim model, produced by ECMWF [10]. The data is obtained in a grid form with a 6-hourly time interval and a spatial analysis of 0.125 degrees, consisting of the u and v components of the wind velocity, at a 10 meter altitude. Furthermore, the matching of the ERA-Interim data with the wind data measured by the Poseidon buoys is validated. These wind data account both for the input to the wave numerical model as well as the raw data for the wind resource.