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Integrated electrification solution for autonomous electrical networks on the basis of RES and energy storage configurations

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ABSTRACT

Most medium and small islands of the Aegean Archipelagos face serious infrastructure problems, strongly related with the limited electrical energy available at extremely high cost. On the other hand, the area is characterized by very high wind speeds and abundant solar energy, thus the exploitation of the available renewable energy sources (RES) may significantly contribute to the fulfillment of the local societies energy demand at minimum environmental and macroeconomic cost. However, the stochastic availability of wind energy and the variable availability of solar energy, the daily and seasonal electricity demand fluctuations, as well as the limited local electrical network capacity result in serious restrictions concerning the maximum renewable power penetration. In this context, the present paper investigates the possibility of creating a combined electricity generation facility based on the exploitation of wind or/and solar potential of an area as well as on the utilization of an appropriate energy storage configuration in order to replace the existing thermal power stations with rational investment requirements. For this purpose, the major parameters of the proposed integrated configuration are firstly calculated and its financial viability is accordingly analyzed. One of the main targets of the proposed solution is to maximize the RES exploitation of the area at a minimum electricity generation cost, while special emphasis is given in order to select the most cost-efficient energy storage device available. According to the results obtained the proposed solution is not only financially attractive but also improves the quality of the electricity offered to the local communities, substituting the expensive and heavily polluting existing thermal power stations.

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1. Introduction

The Aegean Archipelagos is a remote Hellenic area at the east of mainland, including several hundreds of scattered islands of various sizes, Fig. 1. For administrative purposes these islands are divided in five groups, i.e. the islands belonging to Lesvos, Chios, Samos, Cyclades and Dodecanese prefectures. One of the major problems of the area is the insufficient infrastructure, which is strongly related to the limited electrical energy available and the extremely high electricity generation cost of most islands, see for example Fig. 2. In fact, the electricity demand in the Aegean Archipelagos islands has up to now been covered [1] by the existing (30) autonomous power stations (APS), based on internal combustion engines and gas turbines, which belong to the former Greek Public Power Corporation (PPC). The existing APS total installed capacity is approximately equal to 800 MW, while the corresponding electricity generation during 2005 is almost 2200 GWh [2]. Unfortunately there is a significant variation (Fig. 3) of the electricity consumption throughout the year since in most islands the electricity demand during summer season (June–August) represents more than 40% of the total annual consumption, while the corresponding peak load demand is usually two or even three times greater than the mean annual electricity demand [3]. On the other side, the electricity production cost varies between 0.12€/kWh for the big islands and 0.6€/kWh for the small remote Greek islands (Fig. 2), presenting a mean annual increase rate of 5%, during the last 15 years. Note that the corresponding electricity price for domestic users in all Greece is slightly above 80€/MWh, hence the operation of the Aegean Archipelago APS leads to severe financial loss, for the Greek PPC, approaching the 200,000,000€/year. Finally, in almost all these islands there is an extremely urgent need for additional power on annual basis, since the existing APS can hardly meet the corresponding peak load demand [3]. On top of this, the vast majority of the existing thermal power units is very old and should be replaced in the next few years.

At this point it is worthwhile mentioning that the area is characterized by very high wind speeds and abundant solar energy, Fig. 4. Thus the exploitation of the available renewable energy sources (RES) potential may significantly contribute to the fulfillment of the local societies energy demand at minimum environmental

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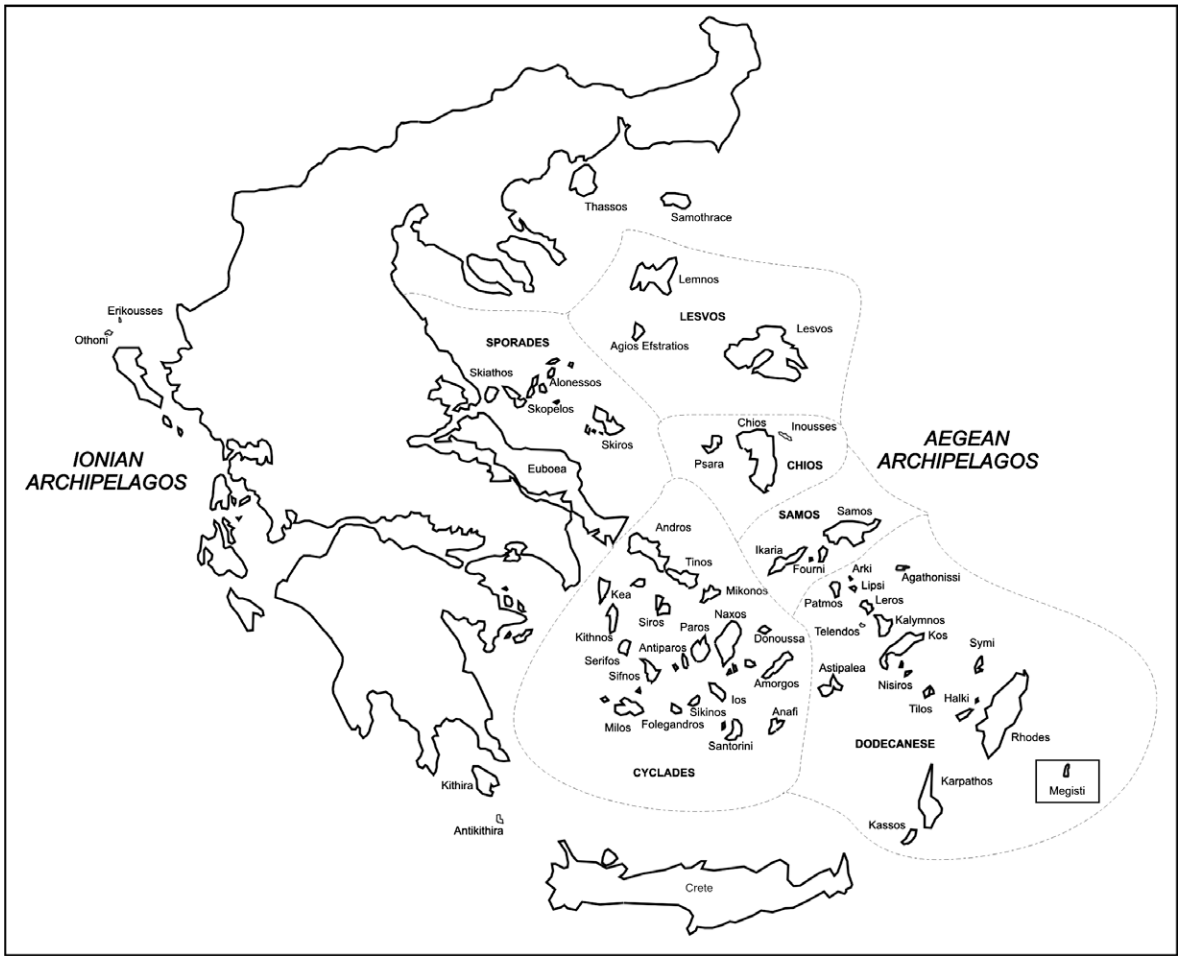

Fig. 1. Aegean Archipelagos complex of islands.

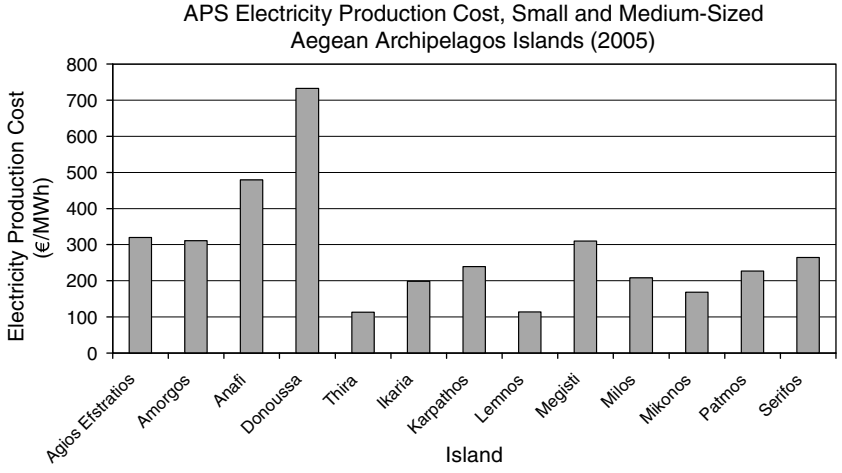

Fig. 2. Electricity production cost of selected Greek APS (PPC, 2005).

and macroeconomic cost [4]. However, the stochastic availability of wind energy and the variable availability of solar energy, the daily and seasonal electricity demand fluctuations, as well as the limited local electrical network capacity result in serious restrictions concerning the maximum renewable power penetration, in order to maintain the local grid stability [5]. For example, until recently, the local electricity utility (PPC) posed a 30% wind power penetration barrier to guarantee the local grid stability. However, even this strict limit has theoretical value, since economic viability criteria [6] deteriorate the maximum wind energy contribution to single digit numbers (i.e. $\leqslant$10%).

According to previous research [7–10] the prospect of creating a combined RES based energy production station with an appropriate energy storage system (ESS) is the only available – for those

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