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Maximum wind potential exploitation in autonomous electrical networks on the basis of stochastic analysis

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ABSTRACT

The vast majority of Aegean Archipelago Islands cover their continuously increasing electricity demand on the basis of oil-fired autonomous thermal power stations, presenting increased operational cost and power insufficiency. On the other hand, this area has a very high wind potential. However, the stochastic behaviour of the wind and the important fluctuations of daily and seasonal electricity load pose a substantial penetration limit for the contribution of wind energy in the corresponding load demand. The problem investigated in the present study concerns the estimation of the maximum wind energy yield, which is acceptable by an autonomous electrical network, on the basis of the probability distribution of the local grid load demand and the corresponding data related to the available wind potential. For this purpose, an integrated numerical method is developed from first principles. More specifically, the proposed calculation method estimates the maximum wind energy contribution on the basis of the existing wind potential data and the information provided by the system operator concerning the corresponding load demand as well as the operational status of the existing thermal power stations. According to the results obtained, one may state that the present situation imposes a quite narrow limit on the wind energy contributing to the fulfilment of the local societies electrical needs. Hence, only by planning and applying an integrated new strategy concerning the incorporation of new wind power in the local networks, including complementary activities, appropriate energy storage installations and improved

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electrical load management, it is possible to increase the wind energy participation in the autonomous Islands electrical networks.

1. Introduction

The Aegean Archipelago is a remote Hellenic area, east of the mainland, including several hundreds of scattered islands. Unfortunately, the electricity production cost for the vast majority of them is extremely high (Kodossakis et al., 1999) approaching 0.25 €/kWh, due to the utilization of aged autonomous (based on diesel electric generators) power stations (APS). At the same time most Aegean Sea islands are characterized by a considerable annual increase of the electrical power demand exceeding the 5% on annual basis (PPC, 2004). In this context, the existing electrification solution cannot meet with reliability the variable load demand; hence in several cases the existing infrastructure cannot fulfil the excessive power demand during the summer period (Kaldellis et al., 2004a).

On the other hand, these islands, along with the mainland coasts, possess a very high wind potential, since in many locations the average annual wind speed exceeds the 9 m/s. Thus wind energy may be an economic attractive solution for their habitants' urgent electrification problem (Kaldellis et al., 2005). Unfortunately, the stochastic behaviour of the wind and the remarkable fluctuation of daily and seasonal electricity load, in almost all island grids, lead to substantial wind energy penetration limits (Kabouris and Perrakis, 2000; Kaldellis, 2001), especially during the low consumption periods of the year. In fact, the Island electrical networks manager (i.e. the Greek Public Power Corporation or PPC) defines an instantaneous upper wind energy penetration limit in order to protect the local grid stability in case the wind energy production is suddenly zeroed. This, up to now empirically chosen value, permits the operating thermal power units to replace the wind power contribution without overloading problems or electrical system voltage and frequency fluctuations.

The proposed analysis is concentrated on developing an integrated methodology which can estimate the maximum wind energy contribution to the existing autonomous electrical grids on the basis of stochastic analysis. For this purpose, one takes into account the electrical demand probability density profile of every island under investigation, as well as the operational characteristics of the existing thermal power stations (PPC, 2004). Accordingly, one also uses the corresponding wind potential characteristics, on the basis of the available wind speed probability density profiles (PPC, 1986). Thus, by combining the electrical load with the corresponding wind potential probability values, one may estimate the resulting wind energy contribution to the local network electricity generation. The proposed methodology is applied to a representative Aegean Archipelago island, in order to demonstrate its applicability in similar problems solution. Finally, the proposed analysis is integrated with an appropriate parametrical analysis, investigating the impact of the available wind potential quality on the expected maximum wind energy contribution.

2. Position of the problem

The problem to be solved in the present study concerns the estimation of the maximum wind energy yield that is acceptable by an autonomous electrical network on the basis of the stochastic distribution of the local grid load demand as well as the corresponding data related to the available wind potential. Hence, for the estimation of the maximum wind energy contribution one needs firstly the corresponding load demand. According to the available measurements (PPC, 2004) one may use either the long-term load demand time series or the corresponding probability density distribution "f_L", see Fig. 1. In fact, one may estimate the probability "P_L", the load demand to vary between two specific values "N_{L1}" and "N_{L2}" as follows

$$P_L(N_{L_1} \leqslant N_L \leqslant N_{L_2}) = \int_{N_{L_1}}^{N_{L_1}} f_L(N_L)\,dN_L \qquad (1)$$