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Distributed Generation in an isolated grid: Methodology of case study for Lesvos – Greece

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ABSTRACT

The purpose of this article is to evaluate the economic effects of Distributed Generation (DG) in isolated grids and in particular Lesvos island in Greece. DG penetration is expected to rise in the following years since the island's wind potential is still not exploited at a satisfying level. The necessity to replace the existing oil-fired power plant together with the need to cut down on greenhouse gases makes DG, and in particular wind turbines quite a promising technology. The present study with the use of specific software simulates the current electricity production for a whole year looking at its technical and economic performance. The sensitivity analysis that is carried out shows the effects of a potential increase in renewable energy sources (RES) capacity. Different sensitivity factors are investigated such as diesel price and hub height. The results show the environmental benefits of increased RES capacity and the variation of the cost of electricity production which remains high compared to other interconnected areas in Greece.

1. Introduction

A large part of the Greek energy sector comprises of isolated power grids. This is the case for most of the islands in the Greek Archipelagos, which are autonomous producers and are based mainly on diesel power plants to produce electricity. Even though there is an abundance of renewable energy sources (RES) such as solar, wind and geothermal ones, their use is limited [1]. Thus, small isolated communities on islands in Greece and in other countries in Europe, such as Denmark, Britain, Sweden, depend on imported oil for their energy needs [2]. Although most of these islands exhibit significant wind potential, the stochastic nature of which, along with the diurnal and seasonal variations in energy demand, limits its exploitation [3].

The entirety of Aegean Sea Islands are characterized during the last decade by a considerable annual increase of the electrical power demand exceeding the 5% in annual basis. This continuous amplifying electricity consumption is hardly fulfilled by several outmoded internal combustion engines usually at a very high operational cost [4]. Solar and wind energy systems are being considered as promising power generating sources due to their availability and topological advantages for local power generations in remote areas. Utilization of solar and wind energy has become increasingly significant, attractive and cost-effective, since the oil crises of early 1970s [5].

The obligation of Greece to lower greenhouse gas emissions as well as to increase the contribution of RES in order to reach 20.1% of the total energy production by 2010, leaves limited options on future energy planning. Community awareness of environmental impact caused by large conventional power plants is growing, together with a greater interest in Distributed Generation (DG) technologies based upon RES [6]. Most of the islands provide a very suitable environment for RES due to their rich wind and solar potential: mean monthly wind speeds range between 6 and 15 m/s (at 40 m height) throughout the year and solar radiation at sea level is between 60 and 230 kW/m^2 [7].

Traditionally, electricity is generated in large power-stations, located near resources or at logistical optima, and delivered through a high-voltage transmission grid and locally through medium-voltage distribution grids. DG aims to add versatility of energy sources and reliability of supply and reduce emissions and dependence on fossil fuels [8]. In recent years as a supplement for conventional large-scale power generation system, DG technologies have got more comprehensive attention. DG represents an alternative paradigm of generating electricity (and heat) at, or close to, the point of demand [9].

At the present time, oil-fired power plants, compared to wind turbines have more than two times lower capital costs and more than three times lower fixed operation and maintenance (O&M) costs. Fixed O&M costs are those costs for operation and maintenance per year that are not related to the amount of electricity

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produced, thus not including fuel consumption. It should be noted that wind turbines have minimum environmental impact compared to diesel power plants, plus the fact that they do not have any fuel costs [10]. As for the economics of wind energy, in the long-term one would expect production costs to go down; whether this will be enough to offset the higher price of inputs will largely depend on the application of correct policies [11]. Also, wind generator electricity costs are heavily linked to the characteristics of the wind resource in a specific location. Cost effectiveness of future wind turbines depend more on having dynamic and compliant design than on increased size [12].

The utilization of wind energy involves different approaches and system architecture. One of the most promising electrification solutions for remote areas with no direct access to interconnected electrical networks is the implementation of hybrid wind–diesel power plants. Especially in the view of the uncertain future concerning oil prices, the continuous air pollution increase and the need to curtail greenhouse gases emissions, a progressive interest in hybrid power-stations is taking place in many regions worldwide [13]. The subsidization possibilities can increase the economic attractiveness of stand-alone hybrid applications [14].

The aim of the present study is to analyze and study the economic and technical effects of an increase in DG penetration for an isolated grid on Lesvos island, Greece. Particularly it is of great interest how an increase in wind production will affect greenhouse gas emissions (environmental), energy production cost (economical) and meeting the electricity demand (technical). The tool used was the HOMER software by the National Renewable Energy Laboratory (NREL). HOMER is a computer model that evaluates design options for both off-grid and grid-connected power systems for remote, stand-alone, and DG applications. HOMER's optimization and sensitivity analysis algorithms allow the evaluation of the economic and technical feasibility of various technology options and is taking into account the variation in technology costs and energy resource availability [15]. HOMER software has been used for simulation of the electricity production of remote places by Weis et al. [16], Himri et al. [17], Rehman et al. [18], and Shaahid et al. [19], etc.

2. Description of the application field

The island of Lesvos covers an area of 1632 square kilometers and is situated in the North East Aegean Archipelagos. It is a medium to large size island with a population of approximately 90,000 habitants. The economic activities are tourism, agriculture, livestock breed, olive oil press and other processing and light industries. As far as electricity generation is concerned, there is a power plant situated in the outskirts of the capital Mytilene and two wind parks which are situated in the west part of Lesvos near Sigri village. The one is owned by the Public Power Corporation (PPC) (39°13.685N, 25°54.808E) and the other one is privately owned (39°12.762N, 25°58.586E).

The energy demand shows a steady increase for the last 10 years as shown in Fig. 10. The annual percentage of increase is about 5.25% according to the data provided by PPC and remains so since the 1980s. The current electricity production capacity is quite low compared to the growing energy needs. It is should also be noted that there is currently no option of external power supply since the island is not interconnected to another grid. As shown in Fig. 1, which represents the simulation of the current electricity production infrastructure, the percentage of excess electricity is quite small.

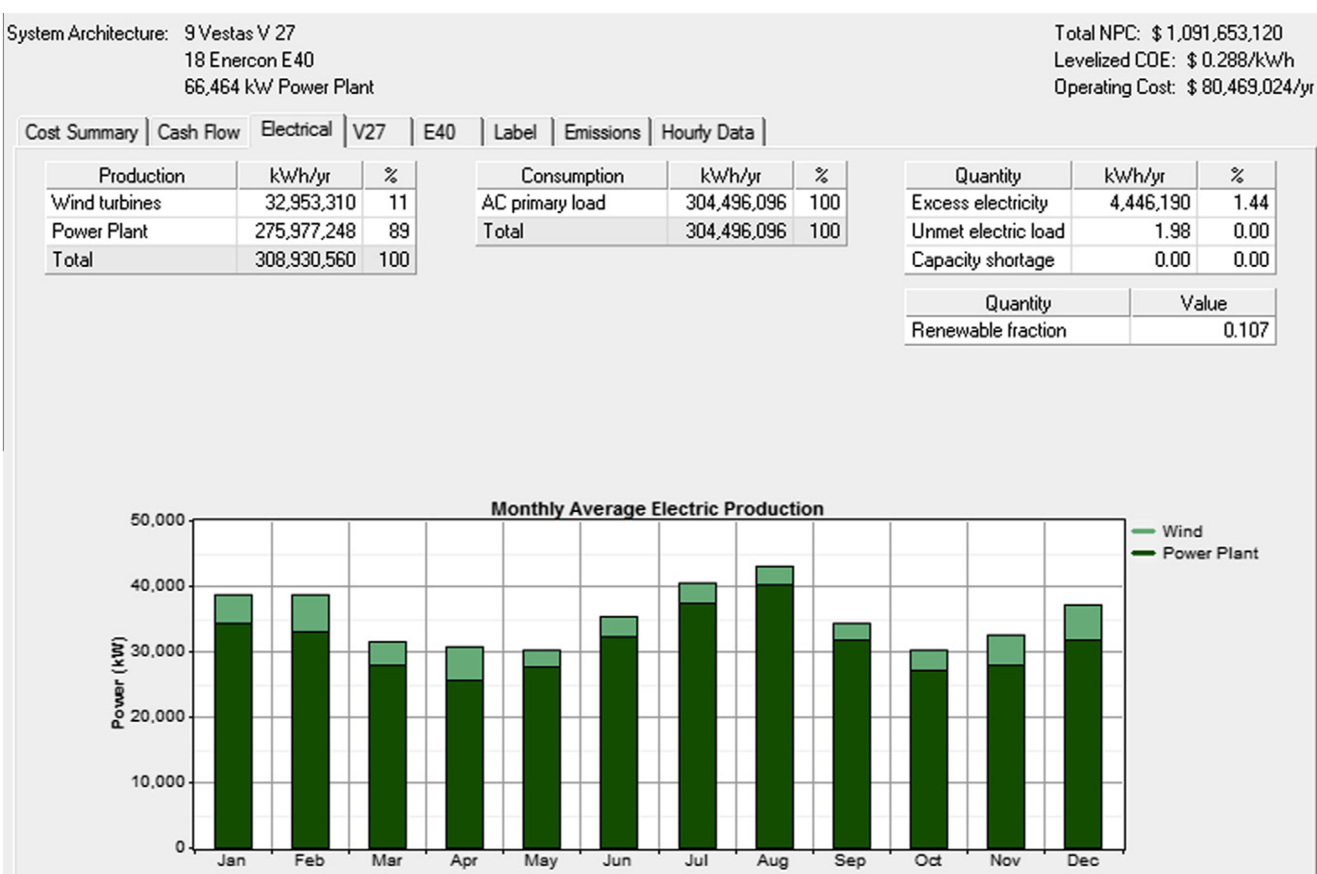

Fig. 1. HOMER's simulation results for electrical output of current electricity generation system.