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Energy storage for renewable energy integration: the case of Madeira Island, Portugal

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Abstract

Energy storage has become a crucial issue regarding renewable energy management, even more important in an island system with the inherent fluctuating operation and inaccurate energy forecast. The growth of decentralized generation in an isolated electrical grid means load stability problems and requires energy storage as a potential solution to guarantee safety and reliability standards. The study described in this paper highlights the need to store energy in Madeira island system and evaluate the operational power dispatch with the introduction of batteries. A simulation tool was developed to quantify the impact of batteries in wind and thermal power plants technologies.

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*Keywords:*Batteries power balance; current scenario; electrical energy storage; isolated grid; re-dispatch; simulation tool

1. Introduction

The development of efficient and environmentally safe energy storage systems is an important and urgent issue to save our society from potentially serious damage due to various pollutants in the atmosphere [1]. Electrical Energy Storage (EES) is a way of converting electrical energy from a power plant into a form that can be stored for

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converting back to electrical energy when needed [2]. This allows the use of intermittent energy sources in peak hours or at any time when no other generation means is available [3]. Distributed electricity generation and the introduction of fluctuating sources like renewable energy, increase the difficulty of stabilizing the power network, mainly due to a supply demand imbalance [4]. More than ever, EES has become a necessity, in particular at isolated electrical systems [5]. When an utility company supplies electricity within a small and isolated power network, the power output from small-capacity generators such as diesel and renewable energy must match the power demand. By installing EES the utility can supply stable power to consumers [6].

This paper aims an analysis on the potential benefits of introducing electrical energy storage in a small isolated system, the case of Madeira, a Portuguese island. We will present a real case study focusing on large-scale batteries and the achieved improvements on grid's management criteria in order to maximize renewable energy injection [7]. In the different scenarios were considered batteries of *NaS* with power between 5 MW and 100MW and capacity between 2.5 MWh and 600 MWh.

2. Madeira energy system characterization

Madeira electrical energy system is based on conventional thermal power plants and hydro plants, complemented by a solid amount of wind energy and steady growing solar energy production. Table 1 shows the power plants existing in Madeira Island's system, detailing the rated power and annual produced energy by each energy technology [8] at the year of 2012. Although renewable energies have been achieving considerable integration in island's energy mix, it is still predominantly dominated by conventional thermal power plants.

Table 1. Energy power plants in Madeira

Source	Thermal	Hydro	Wind	Urban waste	Photovoltaic	Total	Renewables *(%)*
Power *(MW)*	233.94	51.09	43.91	8.00	17.56	354.51	-
Energy *(GWh)*	649.38	74.58	82.62	27.72	27.68	861.9	21

There are two thermal power plants in Madeira, most of the groups supplied by fuel oil and some of them are natural gas generating groups. There is a mix of single and combined cycle, where older and recent energy generation technology coexists. We can find ten hydropower plants in Madeira and the island's hydrography is of small flow water streams type, making it difficult to have big reservoirs. Due to this geographical limitation, nine of the existing hydroplants are run-of-the-river type power plants. Those facilities have a huge strategic importance because they reduce the need for the thermal plants at rainy periods. All the wind power plants are onshore facilities, with a variety of windmill technologies across the island, from full speed control technologies to no control at all. There are still some places with wind potential for building new plants to increase the actual nominal power, wind´s share of the electricity mix increases each year [9]. When it comes to photovoltaics plants, there are two large-scale plants, with 6 MW and 9 MW of rated power. The rest of the installed solar power is about mini and micro producers, with a highly promising future, costs are currently on a fast reducing track, compared to costs of other renewable energy systems [10].

Isolated grid systems face unique conditions that introduce challenges that are different from large mainland power grids. A specific study of technology and applications is needed for that type of energy system.

3. Power dispatch operation: calculation and results

In this work the simulator was developed aiming to replicate the real island system. For a yearly load diagram, we simulate the usual Madeira grid operation and study the impact on the batteries introduction. All data was provided by EEM company [8], concerning the gross annual from all generation technologies, energy grid management and order criteria, with the minute as a time horizon. The method aimed the optimization of battery usage in energy system and renewable energy integration. The power calculation process is based on the difference between power generation and consumption at every moment.

All of the simulated scenarios relate to production values of the year 2012, one-year production diagram from