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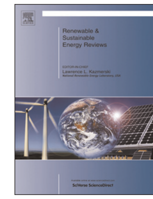

Grid code reinforcements for deeper renewable generation in insular energy systems

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ABSTRACT

Introduction of renewable energy sources (RES) in insular areas is growing on different islands of various regions in the world and the large-scale deployment of renewables in island power systems is appealing to local attention of grid operators as a method to decrease fossil fuel consumption. Planning a grid based on renewable power plants (RPP) presents serious challenges to the normal operation of a power system, precisely on voltage and frequency stability. Despite of its inherent problems, there is a consensus that in near future the RES could supply most of local needs without depending exclusively on fossil fuels. In previous grid code compliance, wind turbines did not required services to support grid operation. Thus, in order to shift to large-scale integration of renewables, the insular grid code ought to incorporate a new set of requirements with the intention of regulating the inclusion of these services. Hence, this paper discusses grid code requirements for large-scale integration of renewables in an island context, as a new contribution to earlier studies. The current trends on grid code formulation, towards an improved integration of distributed renewable resources in island power systems, are addressed. The paper also discusses advanced grid code requirement concepts such as virtual wind inertia and synthetic inertia for improving regulation capability of wind farms and the application of energy storage systems (EES) for enhancing renewable generation integration. Finally, a comparative analysis of insular grid code compliance to these requirements is presented in the European context.

Contents

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1. Introduction

When compared with the progression of renewables on mainland grids insular power systems seem perfect candidates for this energy mix revolution. A preliminary assessment points to large share of RES capacity is possible to integrate due to their higher RES potential [1,2]. However from a conventional viewpoint, insular power grids must keep their balance through resource management and demand prediction for a given time horizon. When elements that their behaviour is not easy to predict are introduced to the power system, keeping the balance of the system becomes a more complex task since the energy balance between the injected and consumed energy should be stable.

RES belong to this type of category providing irregular power due to meteorological and atmospheric conditions. The issue of fluctuations in generated power, caused by variability in wind speed and solar intensity, becomes more pronounced as the penetration of these renewables into the electricity grid increases [3]. Therefore, their stochastic nature will become visible on the power quality of the grid, namely generating transient and dynamic stability issues within the system. Power quality concerns generally associated with RES include voltage transients, frequency deviation, and harmonics. Therefore maintaining the reliability, stability and efficiency of an electrical system becomes a complex issue for insular grids with highly variable energy resources [4].

Despite the aforementioned concerns, a significant presence of RES based installed capacity has already taken place in insular energy grids since these regions are preferable due to high availability of RES [5]. However, moving further towards an increasing share of RES in the generation mix of insular power systems presents a big challenge in the efficient management of the insular distribution network and a serious threat to its normal operation [6]. The implications for non-dispatchable energy resources integration in insular systems can be mitigated through several operational techniques and grid infrastructure enhancement measures such as expanding and planning the island power grid in order to minimise technical constraints brought about the effects of variation in renewable energy generation, by balancing fluctuations with flexible forms of generation (e.g. gas turbines) or as last resort imposing curtailment actions on extreme wind and solar power generation peaks when variable renewable production surpasses significantly the electricity demand. While the first option promotes the grid stability, the other two impose significant financial risk on generation developers [4].

Successful exploitation on mainland grids has proved that it is possible to expand the penetration with reduced wind power curtailment levels under the introduction of new regulations for grid code compliance [7]. A grid code has a particular role in this integration paradigm. Grid codes are basically a set of technical conditions and requirements to be followed when connecting generators to the grid. By complying with these rules the power plant ensures system stability when connected to the grid.

In this context, renewable energy participation on the continental European power grid system, especially with the wind generation, has already considerable penetration which has forced advances on this technology and broader changes on the rules, for its integration through grid codes for the last decade [8]. On a global scale, the most demanding grid code requirements are in the continental Europe, especially for higher penetration levels of renewables, hence, it is considered extremely challenging to respect grid codes during the normal and faulty grid operation by the local grid operators [9–11].

In [12] an in depth analysis on islanded European network situations like UK and Ireland is made, where they have no access to the large interconnected continental network. The study results show that, the grid code requirements are even stricter than the requirements for the continental Europe; driven by the rising level of penetration of wind generation.

In [13] a review of recent grid codes issued in different years for different countries is examined – codes which underline that the wind power plants (WPP) should participate in frequency and voltage control under normal conditions. Meanwhile, during failure – additional requirements and supply of reactive power are considered. In addition, considering the incessant growth of penetration level of wind energy, the requirement of grid codes should be revised and enhanced continuously [13].

In [14] has been presented and informative clarification related with the usual confusion between fault tolerance and grid codes. It has been stated that "in large interconnected power grids, it is incumbent on each generating plant to do its fair share in maintaining the security and reliability of the grid". The ability of a power plant to continue operation after a grid disturbance is governed by: (1) the ability of its generator to recover voltage and remain in synchronism with the power grid after the disturbance (i.e., transient stability) and (2) the ability of its turbine generator and auxiliary systems to remain in operation during and after the disturbance.

A lesson learned from these experiences in islands situation, like Ireland and UK indicates that there are basically two main reasons to put in place stricter grid code requirements in Island systems: the first is the absence of robust grid interconnection comparable to the continental Europe and the second is the need for higher level of wind penetration [12].

In smaller scale insular systems grid code evolution is even more necessary. Typically the power network has limited robustness, poor interconnections and limited short-circuit ratio (SCR). Consequently, these systems are innately prone to frequency and voltage stability problems which can be aggravated with the integration of large share of RPPs [15]. Conversely, small islanded systems are entirely dependant on imported fossil fuels to meet its energy demand. Local grid operators are now aware that there is a significant potential for exploring natural renewable energy