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On Virtual inertia Application in Power Grid Frequency Control

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(*Invited Paper*)

Abstract

To achieve a more sustainable supply of electricity, using distributed generators (DGs) utilizing renewable energy sources (RESs) is a promising solution. However, emerging renewable energy based DGs into power grids reduces the total inertia of the system, and hence, the power grid dynamics and performance can be negatively affected. To address these issues, several inverter control methodologies have been recently proposed for the DGs, and some efforts have been done for introducing the concept of virtual inertia and better understanding of dynamic characteristics of power networks in the presence of high penetration of DGs and RESs. The present paper emphasizes some significant points on the importance of inverter-based virtual inertia on the grid frequency regulation, dynamic impacts, and new relevant ideas to improve power grids frequency stability and control performance.

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Keywords: Distributed generator; Frequency control; Inverter control; Synchronous generator, Microgrid

1. Introduction

The distributed inverter-based power sources are going to become the dominant components in the future power grids. The estimated renewable energy share of global electricity production by the end of 2016 was about 24.5%. Most countries have determined clear plan and target to reach for next few years. For instance, the United Kingdom (UK) and Ireland have set a goal to increase the introduction rate of RESs up to around 40% by 2020, and are planning to export large amounts of wind power from Ireland to the UK [1]. However, integration of numerous

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inverters may create significant challenges in the electric power grid dynamics, mostly due to the reduction of system inertia. As an example, it is predicted that the introduction of a large number of RESs in the UK power grid could reduce the inertial constant to 70% by 2030 [2].

Reducing inertia may significantly magnify the power grid frequency deviation. Frequency deviation is a result of an imbalance between the electrical load demand and the power supplied by connected generators, so it provides a useful index to indicate the generation and load imbalance. A permanent off-normal frequency deviation may affect power system operation, security, reliability and efficiency by damaging equipment, degrading load performance, overloading transmission lines, and triggering the protection devices.

A solution towards stabilizing such a grid is to provide additional inertia, virtually. A virtual inertia can be established for DGs/RESs by using a short term energy storage together with a power inverter/converter and a proper control mechanism. This concept is known as *virtual synchronous generator* (VSG) or *virtual synchronous machine* (VSM). The units will then operate like synchronous generators (SGs), exhibiting amount of inertia and damping properties of conventional synchronous machines. As a result, the virtual inertia concept may provide a basis for maintaining a large share of DGs/RESs in future grids without compromising system stability. The VSG fundamentals and relevant main concepts are well discussed in [3].

Several studies have been done on various types of VSGs, to simulate the dynamic behaviour of an SG, and represent the inertia and damping property from its fundamental swing equation, which not only enables the stand-alone operation of a VSG or parallel operation of multiple VSGs, but also enhances the frequency stability of power grids. Since to enhance the dynamic response, the parameters of the VSG control loops can be easily tuned in the software program, the VSG concept is known as a useful solution for improving the resilience of the electric power networks [4, 5].

The present paper contains the following sections: first the fundamentals and main concepts of VSG control are introduced. Then, the impact of virtual inertia (VSG) on the grid active power and frequency response is analysed. In continuation, an updated frequency control scheme is presented, and finally, the paper is concluded.

Nomenclature

AGC	automatic generation control
DC	demand control
DG	distributed generator
DR	demand response
EC	emergency control
IC	inertia control
LFC	load-frequency control
MG	microgrid
PC	primary control
P-F	power-frequency
PWM	pulse width modulation
RES	renewable energy source
SC	secondary control
SG	synchronous generator
TC	tertiary control
UFLS	under frequency load shedding
VSG	virtual synchronous generator

2. VSG control

The VSG consists of three fundamental components as shown in Fig. 1a: energy source, inverter, and a control mechanism. The VSG serves as an interface between a primary energy source and the grid. In the VSG control