FUTURE FREQUENCY STABILISATION BY INNOVATIVE HYDRAULIC VARIABLE INERTIA FLYWHEEL

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Introduction

Driving forward the energy transition to achieve climate targets is a challenge for the energy industry on multiple levels. The expansion of fluctuating renewable energies leads to an increase of imbalances between electricity generation and demand which results in frequency deviations [1]. Therefore, frequency stabilisation is one challenge to ensure the security of supply in a future 100 % renewable power system.

Nowadays, the frequency of the continental European electricity grid is inherently stabilised by the inertia provision of conventional technologies due to their inertial mass rotating synchronously connected to the grid. The renewable energies photovoltaic and wind are connected via frequency converters and thus do not provide inherent inertia today. The reduction of conventional power plants and the expansion of renewable, converter-based technologies are consequently leading to a reduction of system's inertia which effects the frequency stability negatively. For this reason, technological, regulatory and economic changes and innovations are needed to ensure the functionality of the power system in future. [1]

This article focuses on an innovation for future frequency stabilisation: the hydraulic, variable inertia flywheel (HVI-FW) [2]. Due to its variable moment of inertia, HVI-FW exchanges energy with the grid while rotating at a quasi-constant speed. Connected to the grid via a synchronous machine of rotating power generator or load, it provides inertia inherently and offers a grid-forming effect. Even though grid-forming frequency converters will play a significant role in providing inertia in the future [3], HVI-FW offers a complementary solution that does not require controls, i.e. software and communication. Hence, it is inherently secure against software bugs, communication network interruptions and cyber attacks [2].

The aim of this paper is to investigate the potential inertia provision of HVI-FW in Germany when connected to already existing rotating generators of suitable rating.

Methodology

In order to identify the potential inertia provision via HVI-FW, a design tool is used to determine suitable geometries and the corresponding energy output for inertia provision [4]. In order to use existing infrastructure, it is assumed that HVI-FW is connected to all synchronously rotating electric generators in Germany. An overview about those power plants is offered by the German core energy market data register [5]. It is assumed that the rotating conventional power plants are connected synchronously to the grid and HVI-FW is attached to those. The design tool considers a frequency range from 47.5 to 51.5 Hz. The flywheel should be able to charge and discharge energy within this speed range. A geometry is defined as suitable if certain criteria are met. Assuming an inertia constant of 10 s, one criterion is a minimum additional stored energy of 10 kWs so that the average power output is 1 kW. Another criterion is whether HVI-FW offers an advantage compared to a conventional flywheel. This is the case if the specific energy of HVI-FW is greater than that of a conventional flywheel storing the same amount of energy at the same outer radius and height.

Results

Figure 1 shows the energy which can be provided additionally by HVI-FW during a frequency change from 50 to 47.5 Hz for a range of radii and heights. Only the suitable geometry combinations that meet the criteria are shown. The higher the radii and the total height of HVI-FW is the more energy is stored.

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The energy ranges from 19 kWs (0.03 m, 0.25 m, 1.2 m) to 1,458 kWs (0.09 m, 0.575 m, 1.6 m). Taking into account the time of 10 s for the inertia provision the available power ranges consequently between 1.9 kW and 145.8 kW maximum. Due to the German core energy market data register, there are 13,993 conventional power plants in use which have a rated power between 1 kW and 145 kW [5]. By installing the HVI-FW as an additional rotating mass on these power generators, the discharge of the HVI-FWs amounts to around 5.12 GWs during a frequency decrease from 50 to 47.5 Hz. The inertia provision by HVI-FW is compared to inertia of the generators it is attached to. Making a conservative approach by assuming an average inertia constant of 4 s [6], the energy amounts to around 2 GWs. By attaching HVI-FW to those generators, their kinetic energy can be more than tripled (7 GWs). By utilising existing, spatially well-distributed infrastructure, the innovative HVI-FW offers a relevant inertia potential that is substantial for future frequency stabilisation and thus the security of supply.

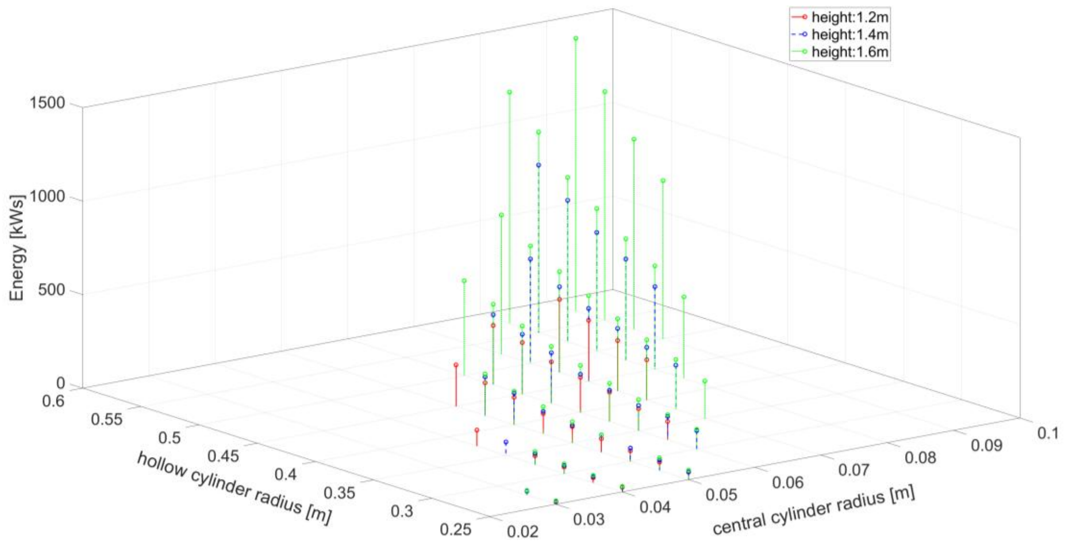

Figure 1: Discharged energy during a frequency decrease from 50 to 47.5 Hz for suitable geometries of HVI-FW

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