

Impact of Inertia Emulation Control of Grid-Scale BESS on Power System Frequency Response

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Abstract— Battery Energy Storage System (BESS) becomes important for many applications, including frequency regulation and control. This paper presents a comprehensive analysis of all the electro-mechanical-chemical variables involved in improving the system frequency response. It also evaluates the impact of including inertial emulation control of grid-scale BESS on the system frequency response of classical transmission systems. In order to investigate this impact, several simulation case studies are carried out, with different sudden generation outages and load disturbances with different power supply capacities. All case studies are combined with time-domain events to inspect the dynamic behavior of the frequency response of grid-scale battery. The purpose of this paper is to investigate the inertial response to design a set of algorithms to control the output of the inertial controller.

Keywords—Frequency Response, Inertia Emulation Control, Grid-Scale BESS.

I. INTRODUCTION

In recent years, the power system has undergone a massive transformation in terms of changing infrastructure and introducing control technologies. The foremost consideration of this change is principally represented by replacing some of the Conventional Power Plant (CPP) that is predominantly operated by fossil-fuel with environmental friendly energy resources, such as Wind Power Plant (WPP) and photovoltaic and solar power. This transformation has brought considerable ecological and economic benefits; however, this does not come without a price. Normally, CPP is more controllable and convenient for power system stability in contrast to new generation resources, such as Renewable Energy Resources (RES). Most RES is characterized by their intermittency and uncontrollable nature, and they mostly depend on the weather forecast to provide electric power. CPP can provide frequency response to preserve the balance between the demand and load, which is essential for power system stability.

Frequency response is classified, based on the time of reaction, into three broad categories: Inertial Response (IR), Primary Frequency Control (PFC), Secondary Frequency Control tertiary control. PFC and secondary frequency control are provided by two main control techniques: turbine governor and Automatic Generation Control (AGC), respectively. However, IR inherently exists in the system and is part of it. Because it principally arises due to the physical phenomena of

kinetic energy generated and stored in all rotating parts of load motors and synchronous generators. If any disturbance occurs, power imbalance in the power system unpreventably follows; this kinetic energy is released in parts of a second to arrest this change and prevent the system frequency going under limits. With the help of previously mentioned system control strategies, the inertial response can bring the frequency to its scheduled value in few seconds to minutes. Therefore, the grid inertial frequency response is a fast frequency response, and it is an important factor in power system stability, especially during the early stage of system frequency disturbance.

With introductory of RES, these three control strategies become less effective. IR is mainly affected, since most RES are connected to the grid through electronic converters and provide significantly no IR to the grid [1]. New control techniques are introduced to use with such intermittent energy sources. Control strategies, such as Maximum Power Point Tracking (MPPT) and inertial emulation techniques, use ESS, mainly BESS. The influence of different ESS, specifically BESS and flywheels, on large power system frequency responses were studied by [2]. In another paper, [3] develops two control strategies, Coordinated Constant Droop Control (CCDC) and Coordinated Adaptive Droop Control (CADC), to emulate the grid inertial response with the aid of BESS and Flywheels.

The main benefits of using BESS for frequency control comes from three main points. First, it replaces the fast start reserves gas turbine, preserved to be used if any disturbance occurs. Second, its fast response would replace and substitute the online reserve generators; therefore, it works as a supplementary PFC. It supports the system inertial response and acts as an alternative to the declined inertia. Current breakthrough in developing BESS promises extensive use in coming years.

In this paper, sensibility analysis is used to examine how the parameters of BESS controller effect electro-mechanical-chemical variables related to the frequency response. This paper evaluates the impact of changing the gain of inertial emulation controller H_{BESS} of the grid-scale BESS on the system frequency. Many time-domain simulation case studies, using DIGSILENT PowerFactory, are applied to evaluate the system frequency response with changeable several values of H_{BESS} disturbances. The outcomes of this time-domain analysis study

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