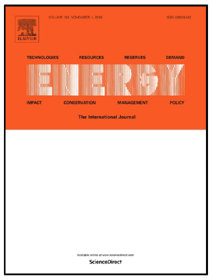

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Abstract

Flywheel energy storage systems (FESSs) store kinetic energy in the form of $J\omega^2/2$, where J is the moment of inertia and ω is the angular frequency. Although conventional FESSs vary ω to charge and discharge the stored energy, in this study a fixed-speed FESS, in which J is changed actively while maintaining ω, was demonstrated. A fixed-speed FESS has the advantage of being capable of direct grid-connection without requiring a power electronic interface. A prototype with an output power of several hundred watts and a charge/discharge period of several seconds has been developed and discharge/charge operations have been conducted while mechanically measuring the output energy E_m from the flywheel and mechanical work E_c, to vary J. Theoretical analysis suggests a ratio of 2.2 for E_m/E_c, and experimental values of E_m/E_c show high reproducibility, approximately 1.8 and 2.7 in discharge and charge operations, respectively. The reason for the errors can be explained by the loss incurred in varying J.

Keywords: flywheel energy-storage system, variable inertia, fixed speed, induction machine, efficiency

1. Introduction

In recent years, the capacity of solar and wind power generation for providing secure energy without fossil fuel input or radioactive waste production has increased. However, the output power produced by photovoltaic (PV) and wind power generation systems fluctuates with a degree of uncertainty linked to the variation of weather conditions such as solar irradiance and wind speed. Furthermore, such sources provide little or no inertial contribution of the type provided by conventional thermal power plants connected to the grid through huge synchronous generators. These factors are of great concern, as frequency deviation and a high rate of change of frequency (RoCoF) can arise from demand and supply imbalances and inertial limitations in electric power systems [1,2].

One solution to these problems is the use of energy storage systems, which can help maintain grid balance by charging during periods of excess power generation and discharging during reduced generation periods [3,4,5]. Although pumped-hydro power generation is currently the most widely used storage technique, facilities are often located far away from primary consuming regions, as they require the use of upper and lower water reservoirs. Battery energy storage systems with a