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Modelling and performance assessment of a standalone hybrid wind-diesel-superconducting magnetic energy storage system using four-quadrant operation of superconducting magnetic energy storage

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Abstract

In this article, a comprehensive model for power quality assessment of a standalone wind-diesel-superconducting magnetic energy storage system is developed using firing angle control scheme of superconducting magnetic energy storage unit. A four-quadrant operation of superconducting magnetic energy storage unit is proposed where firing angle of superconducting magnetic energy storage converter is controlled depending upon active and reactive power demand of wind-diesel system, under various disturbances. Superconducting magnetic energy storage is designed as a controllable current source capable of reducing both frequency and voltage deviations simultaneously. For continuous control of superconducting magnetic energy storage unit, a regulating variable is formulated which forces the superconducting magnetic energy storage current to return to its nominal value after handling a disturbance in order to handle a new disturbance. Frequency of the system is estimated using the concept of centre of inertia. System performance is assessed for disturbances of higher magnitudes. Complete modelling is carried out in MATLAB/Simulink environment, and simulation results demonstrate that the scheme gives expected results under load disturbance and wind perturbations.

Keywords

Power quality improvement, wind-diesel-superconducting magnetic energy storage system, controllable current source, four-quadrant operation, regulating variable, centre of inertia, wind perturbation, load disturbance, MATLAB/Simulink

Introduction

Renewable energy sources are widely being used because of their outstanding advantages over conventional energy sources. Among all the renewable energy sources, wind energy conversion system (WECS) is the most popular and fast growing. WECS-based power systems are most suitable for habitations which are not grid connected or where power is supplied from diesel-generating units. The integration of wind power system with the already existing diesel-generating system increases the reliability of the power system and reduces the cost of fuel (Das et al., 1999; Kusakana and Vermaak, 2014). Integrating a WECS with a diesel-generating system is, however, a challenging task. Since the inertia is low, any disturbance in the system will cause electromechanical oscillations and deteriorates the power quality (Salih et al., 2014; Sheikh et al., 2009). Power quality problem can, however, be solved by incorporating a superconducting magnetic energy storage (SMES) unit as buffer storage. Advantage of SMES is that it is fast acting with almost zero self-discharge. The coil is kept at a very low temperature with the help of cryogenic coolers, so the ohmic losses are close to zero during the

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