A Study on the Application of a Superconducting Fault Current Limiter for Energy Storage Protection in a Power Distribution System

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***Abstract*—This paper presents the application of a superconducting fault current limiter to energy storage for protection in a power distribution system. An energy storage system is increasingly being used to help renewable energy resources integrate into the grid. It is important to keep an energy storage system interconnected with the grid without interruption and to supply electrical power to the grid. The main objective of this paper is to introduce a superconducting fault current limiter to keep the energy storage system from disconnecting from the grid when ground faults occur. Its effect is analyzed using transient simulation software.**

***Index Terms*—Energy storage, fault current, interconnecting transformer, superconducting fault current limiter.**

I. Introduction

In recent years, more energy storage systems (ESSs) have been interconnected with the power grid in the form of distributed generation units (DGs) owing to growing interest in the environment and energy depletion. An ESS enables energy to be stored when there is an excess of supply and supplies excess energy to loads to compensate for a deficit in supply [1]. ESSs are increasing their impact on the power grid as a solution to stability problems. The one of the main advantages of energy storage is to contribute to the quality of the grid by maintaining the power constant [2]–[4].

Energy storage technologies are essential for modern power systems. Although an ESS does not generate energy, its function appears to be vital for the operation and planning of an electrical power system, particularly for the stability, reliability, and power quality of the power output. In addition, the system defers the costs and upgrades of developing the transmission and distribution capacity for satisfying the growing power demand for peak-shaving purposes. The ESS is installed to enhance the dispatching ability of renewable energy sources and to provide ancillary services such as reactive power support for operations [5]–[7].

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Although an energy storage system adds a number of benefits for power systems, it has a drawback which is concerned with the protection for a single line-to-ground fault current, similar to a DG [8]. There are various types of transformer connections that interface a generator to an existing power system and provide essential isolation [9]. In particular, a grid-side grounded wye-delta winding connection is prevalent for use in interconnecting all central station generation to the utility systems [8]. The energy storage is interfaced with the power system in this connection. The ground fault current trips a ground overcurrent relay on a four wire, multi-grounded neutral distribution systems. In addition, it can disrupt the coordinated power system protection and subsequently disconnect the energy storage from the grid. The presence of energy storage on the distribution feeder introduces new sources of ground fault currents that can change the direction of the fault current and protective relay coordination. The application of super-conducting fault current limiters (SFCLs) to an ESSs for a stable operation of the distribution system has been recognized as one of the promising solutions for fault current problems, because of its fast fault current limiting and automatic characteristics of recovery [10]–[16].

The effect of an SFCL applied to an interconnecting transformer for an ESS is analyzed. A resistive SFCL and distribution system with energy storage has been modeled using the transient simulation software package PSCAD/EMTDC and is described in Section II. Section III describes the effects of fault current limiting not disrupting the protective relay coordination between the distribution system and ESS according to our case studies. Finally, the conclusions are presented in Section IV.

II. Modeling of an SFCL and Distribution Power System With an Energy Storage System

A. Resistive SFCL Model

An SFCL is one of the most promising current limiters to prevent the short-circuit current from increasing in magnitude owing to its rapid current limiting ability. Many models for an SFCL have been developed, such as resistive type, reactive type, transformer type, and hybrid type SFCLs [10], [13]. Among the various types of SFCLs, the resistive type SFCL is preferred because of its simple principle and compact structure of small size [11]–[13]. In this paper, we have modeled a resistive type SFCL using mathematical expressive equations,