Fault Current Limiter Testing Requirements

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1.0 INTRODUCTION

The U.S. electric grid is an essential part of American life. However, there is a well-recognized need to modernize America's electric grid, and the development and deployment of "next generation" electric transmission and distribution (T&D) equipment is a key part of this. With the limited investment in research and development (R&D) to create and test advanced electricity-delivery technologies, grid modernization will be a more difficult goal to attain.

Testing of Zenergy's FCL device

For example, most of the existing T&D infrastructure is reaching the end of its useful life, and coupled with steady growth in electricity demand there is increasing electricity congestion and reduced electric reliability in several areas of the country. To help address these problems, with R&D funding from the U.S. Department of Energy (DOE), equipment manufacturers, electric utilities, and researchers from private industry, universities, and national laboratories are teaming up to spur innovation and develop new technologies, tools, and techniques.
Because of these efforts, the future electric grid will likely incorporate technologies very different from those that have been traditionally installed.

Some examples of these new technologies include solid-state and superconducting equipment, which are already making their way into the T&D system. Testing new T&D equipment is generally required by utilities to ensure that new devices being introduced in the grid will perform as expected and not have adverse effects on the electric system. The standards and protocols for testing conventional T&D equipment are well known and are referenced routinely. The Institute of Electrical and Electronics Engineers (IEEE) and the National Electrical Manufacturers Association (NEMA), each promulgate standards for electric power sector equipment. IEEE's members are electrical engineers; NEMA's members are firms that manufacture equipment. Another organization, American National Standards Institute (ANSI), does not promulgate standards but adopts standards from organizations such as IEEE or NEMA. Several international standards groups include the International Electrotechnical Commission (IEC) and the International Organization for Standards (ISO). CIGRE, the International Council on Large Electrical Systems, formed the A3.10 working group and published a technical brochure in 2003 which included a very limited set of recommendations for testing fault current limiters in medium- and high-voltage systems.[1] CIGRE Working Group A3.23 was created in 2008 and is working on the application and feasibility of fault current limiters in power systems. IEEE is currently working on establishing a task force on FCL testing. However, there are currently not any standards for testing high-temperature superconducting (HTS) and solid-state fault current limiters and integrating the device with the electric system. These devices are too new and are still in the research and

[1] CIGRE Brochure 239, *Fault current limiters in electrical medium and high voltage systems*

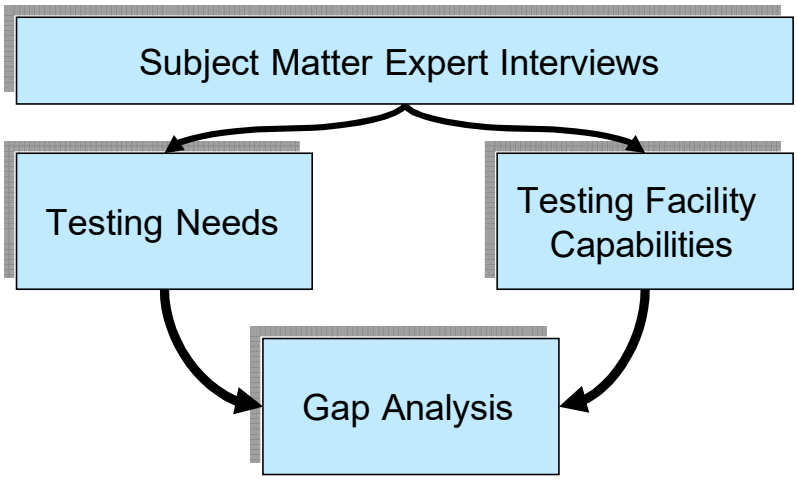
development phase. Testing recommendations have been developed by utilities and device manufacturers on a case-by-case basis. Once these devices are scaled up and ready to be fully tested, there are questions about whether or not the facilities exist to test them properly.

This situation is problematic because there is a growing need for fault current limiters (FCLs) on the electric grid, and inadequate facilities and testing standards could delay their deployment. Superconducting power equipment could be an important element in the effort to modernize the electric grid and promote grid security and efficiency. A considerable amount of R&D progress has been made in the last few years, and several electric utilities are beginning to include superconducting cables in their planning horizon. The U.S. Department of Energy is currently supporting solid-state and high-temperature superconducting (HTS) fault current limiter demonstration projects. As data from these projects become available, and as utilities begin to consider where and how to use them, there will be a growing need for standardized testing of these components.

Methodology

The “logic flow” of the methodology used to develop this course is shown in Figure 1. The work included interviews with experts from equipment manufacturers, electric utilities, universities, consultancies, and national laboratories on their experience with testing various T&D equipment and identifying testing requirements. In parallel, research was conducted to evaluate the capabilities of existing testing facilities in the U.S. and around the world. A gap analysis was performed based on the testing needs and test facility capabilities.

Figure 1. Methodology Flow Chart



Organization of the Report

The testing procedures and brief project status reports can be found in Chapter 2. During the interviews, the experts were also asked about the testing facilities with which they had experience. Based on these responses, an evaluation was conducted of the high-current and high-voltage facilities in the U.S. and abroad. The evaluation also involved discussions with representatives of the test facilities and a literature search. This information can be found in Chapter 3. After the interviews were conducted, a gap analysis was performed, which can be found in Chapter 4. Chapter 5 contains an assessment of the options for next steps in the development of testing facilities.

Appendix A contains a list of references used in the report. The list of experts can be found in Appendix B. Appendices C, D, E, and F contain testing information from the various Department of Energy-sponsored fault current limiter projects.

2.0 TESTING PROCEDURES FOR FAULT CURRENT LIMITERS

FCL Testing Procedures

DOE is conducting three high-temperature superconducting (HTS) and one solid-state fault current limiter projects. The three HTS projects involve the following companies: American Superconductor Corporation, SuperPower Incorporated, and Zenergy Power. The solid-state fault current limiter project involves the Electric Power Research Institute (EPRI) and the Silicon Power Corporation (hereafter referred to as Silicon Power). Additional information about each of these projects is contained in the text below and in Table 1.

Currently testing for fault current limiters is based on a hybrid test procedure for various existing equipment. For instance, the National Electric Energy Testing, Research and Applications Center (NEETRAC) worked with several manufacturers to develop testing procedures to validate their fault current limiter concept. Test procedures were derived from protocols for testing breakers, transformers, and reactors. Testing requirements need to be compatible with existing standards, taking into account the unique characteristics of the FCL.

The most important benefit of FCL in utility systems is the possibility to upgrade the electric grid to higher transmission capabilities while maintaining existing fault current limits for transformers and circuit breakers. This could save utilities money because they will no longer have to upgrade or retrofit existing equipment on their lines when they want to increase their transmission ratings. One of the delays to the faster adoption of FCLs is that currently, there are no standardized testing procedures in place for fault current limiters. While R&D efforts have been advancing, the current testing protocols are still very preliminary, and they have been set up based on each manufacturer's and hosting utility's specifications.

Because all four DOE projects are still prototypes, manufacturers are still conducting R&D testing and not type testing[4]. Testing of commercial-ready transmission class devices is still approximately 5 years away. R&D tests allow the manufacturers to explore the different parameters of the device being developed, such as the number of conductors needed or the size of the FCL coil to improve their design. These tests allow each parameter to be changed several times to validate different FCL functions. Type tests involve the evaluation of the device's functions, such as the time it takes to limit a fault or the maximum current and voltage that the device can withstand. It is important to note that as of today, there are no guidelines for type testing. From the ongoing R&D projects, and the rating that they are targeting, we can identify likely scenarios that a type test will include.

[4] Type testing refers to testing commercial scale devices

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