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Improvement of Protection Co-Ordination and Stability Enhancement of Distribution Network with Dg Using VSC Based Converter

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Abstract:

Utilization of renewable energy resources is the demand of today and the necessity of tomorrow. For a power distribution system with DG units, its fault current and induced overvoltage under abnormal conditions should be taken into account seriously. In consideration that applying superconducting fault current limiter (SFCL) may be a feasible solution. Distributed Generation Resources are increasingly used in distribution systems due to their great advantages. The presence of DG, however, can cause various problems such as miss-coordination, false tripping, blinding and reduction of reach of protective devices.

Using superconducting fault current limiters (SFCLs) is one of the best methods to minimize these problems comparing to the other conventional methods. The active SFCL can as well suppress the short-circuit current induced by a three-phase grounded fault effectively, and the power system's safety and reliability can be improved and it is composed of an air-core superconducting transformer and a PWM converter. The magnetic field in the air-core can be controlled by adjusting the converters output current, and then the active SFCLs equivalent impedance can be regulated for current limitation and possible overvoltage suppression. During the study process, in view of the changes in the locations of the DG units connected to the system, the DG unit's injection capacities and the fault positions, the active SFCLs current-limiting and over voltages suppressing characteristics are presented by using Matlab/Simulink software.

***Index Terms—* Distributed generation (DG), distribution system, overvoltage, short-circuits current, voltage compensation type active superconducting fault current limiter (SFCL).**

I. INTRODUCTION

Electric power systems are designed such that the impedances between generation sources and loads are relatively low. This configuration assists in maintenance of a stable, fixed system voltage in which the current fluctuates to accommodate system loads. The primary advantage of this arrangement is that loads are practically independent of each other, which allows the system to operate stably when loads change. However, a significant drawback of the low interconnection impedance is that large fault currents (5 to 20 times nominal) can develop during power system disturbances.

In addition, the maximum fault current in a system tends to increase over time for a variety of reasons, including Electric power demand increases (load growth) and subsequent increase in generation, Parallel conducting paths are added to accommodate load growth, and Interconnections within the grid increase, Sources of distributed generation are added to an already complex system. In an effort to prevent damage to existing power-system equipment and to reduce customer downtime, protection engineers and utility planners have developed elaborate schemes to detect fault currents and activate isolation devices (circuit breakers) that interrupt the over-current sufficiently rapidly to avoid damage to parts of the power grid. While these traditional protection methods are effective, the ever-increasing levels of fault current will soon exceed the interruption capabilities of existing devices.

Shunt reactors (inductors) are used in many cases to decrease fault current. These devices have fixed impedance so they introduce a continuous load, which reduces system efficiency and in some cases can impair system stability. Fault current limiters (FCLs) and fault current controllers (FCCs) with the capability of rapidly increasing their impedance, and thus limiting high fault currents are being developed. These devices have the promise of controlling fault currents to levels where conventional protection equipment can operate safely. A significant advantage of proposed FCL technologies is the ability to remain virtually invisible to the grid under nominal operation, introducing negligible impedance in the power system until a fault event occurs.

Ideally, once the limiting action is no longer needed, an FCL quickly returns to its nominal low impedance state. Superconducting fault current limiters (SFCLs) utilize superconducting materials to limit the current directly or to supply a DC bias current that affects the level of magnetization of a saturable iron core. While many FCL design concepts are being evaluated for commercial use, improvements in superconducting materials over the last 20 years have driven the technology to the forefront. Case in point, the discovery of high-temperature superconductivity (HTS) in 1986 drastically improved the potential for economic operation of many superconducting devices.

II. THEORITICAL ANALYSIS

The concept of using the superconductors to carry electric power and to limit peak currents has been around since the discovery of superconductors and the realization that they possess highly non-linear properties. More specifically, the current limiting behavior depends on their nonlinear response to temperature, current and magnetic field variations. Increasing any of these three parameters can cause a transition between the superconducting and the normal conducting regime. Resistive SFCLs utilize the superconducting material as the main current carrying conductor under normal grid operation.

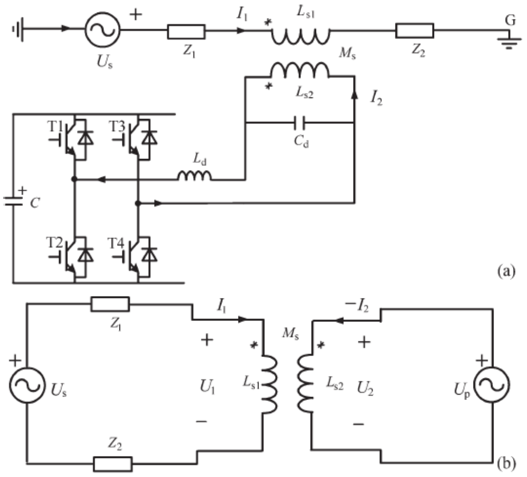

Fig.1. Single-phase voltage compensation type active SFCL. (a) Circuit structure and (b) equivalent circuit.

One of the first SFCL designs developed for grid deployment was the shielded-core design, a variation of the resistive type of limiter that allows the HTS cryogenic environment to remain mechanically isolated from the rest of the circuit. An electrical connection is made between the line and the HTS element through mutual coupling of AC coils via a magnetic field. Unlike resistive and shielded-core SFCLs, which rely on the quenching of superconductors to achieve increased impedance, saturable-core SFCLs utilize the dynamic behavior of the magnetic properties of iron to change the inductive reactance on the AC line. As shown in Fig. 1(a), it denotes the circuit structure of the single-phase voltage compensation type active SFCL, which is composed of an air-core superconducting transformer and a voltage-type PWM converter. By neglecting the losses of the transformer, the active SFCL's equivalent circuit is shown in Fig. 1(b). As shown in Fig. 2, it indicates the application of the active SFCL in a distribution network with multiple DG units, and the buses B-E are the DG units' probable installation locations.

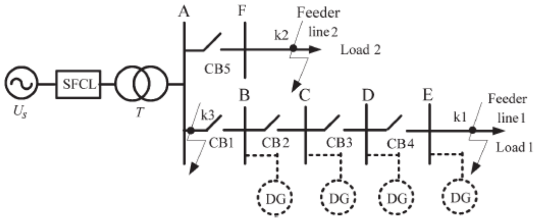

Fig.2. Application of the active SFCL in a distribution system with DG units.

When a single-phase grounded fault occurs in the feeder line 1 (phase A, k1 point), the SFCL's mode 1 can be automatically triggered, and the fault current's rising rate can be timely controlled. Along with the mode switching, its amplitude can be limited further. In consideration of the SFCL's effects on the induced overvoltage, the qualitative analysis is presented. Superconducting materials have improved considerably over the past few decades.

As a result, several applications have developed to a stage where superconductivity is the enabling technology. These include high-energy particle accelerators, magnetic resonance imaging systems, and highly sensitive RF detectors for cell phone towers, high magnetic field magnets for scientific research, and so on. As superconductors became available for commercial devices, the need for standards became clear. The initial effort on standards—under the auspices of the International Electro technical Commission (IEC)—was in the areas of measurements and conductor performance. This activity has continued to the present by the IEC Technical Committee 90 (TC-90) and has expanded from the initial critical current measurements on low temperature superconductors so that it now includes some measurements and procedures for high-temperature superconductive materials. IEC TC-90 is chaired by Dr. Loren Goodrich of the U.S. National Institute of Standards and Technology (NIST). The major player in each IEC TC is the secretariat, which for TC-90 is hosted by Japan. Efforts are in place by the IEC to establish other types of standards in the superconducting arena, for example in the area of current leads. Otherwise, there has been little activity until now on developing standards for superconductor-based applications. There are several reasons for this situation. First, the high-energy physics world has been the driver for the use of low-temperature superconductors (LTS). They use thousands of superconducting magnets, but they all operate in a laboratory environment and are either one-of-a-kind devices or a single system that uses hundreds or even thousands of identical magnets that work in concert.

Specifications are written for these applications, but they do not require general standards. However, it is significant that the high-energy physics community supports a broad-based collaborative effort to improve the capabilities of some of these materials and has been instrumental in developing standards for LTS wire. Standards for magnetic resonance imaging (MRI) technology have been under the control of the organizations that regulate the safety of medical systems. As a result, they have been designed to meet stringent safety requirements, but performance and component standards have mostly been company proprietary. There has been little demand for additional standards on the superconductive materials used in the magnets.

III. SIMULATION RESULTS

For purpose of quantitatively evaluating the current-limiting and overvoltage-suppressing characteristics of the active SFCL, the distribution system with DG units

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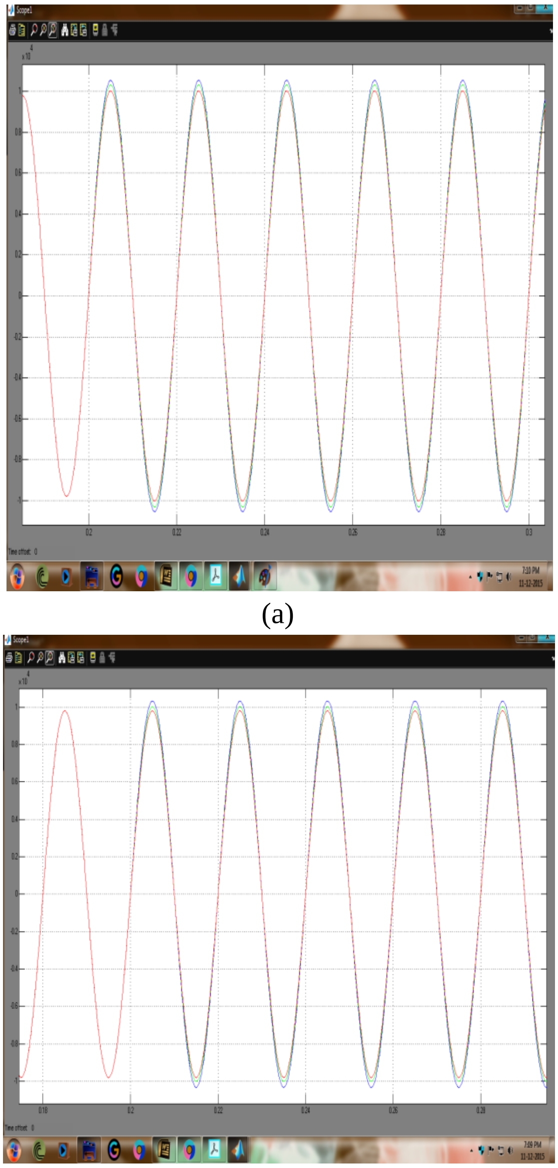
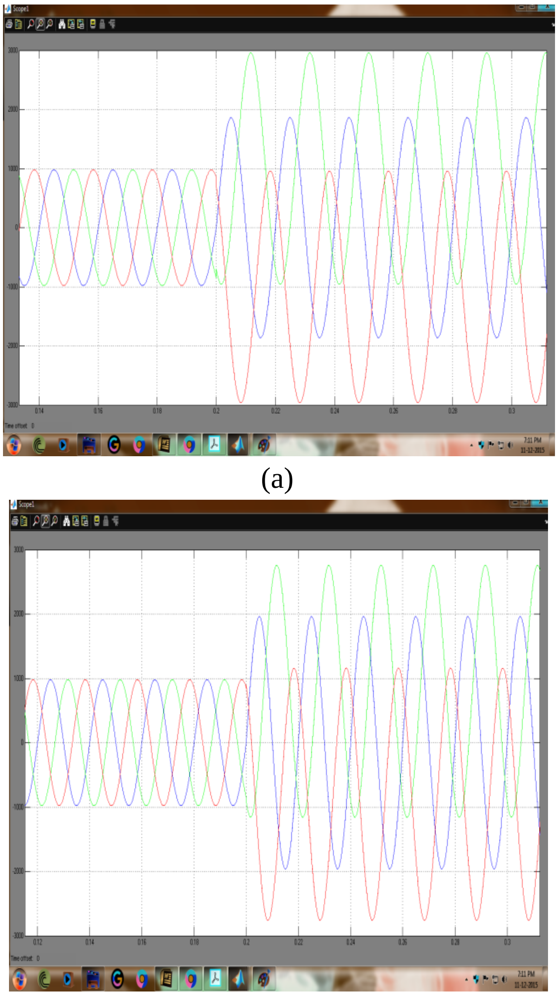
and the SFCL, as shown in Fig. 2 is created in MATLAB. The SFCL is installed in the behind of the power supply Us, and two DG units are included in the system, and one of them is fixedly installed in the Bus B (named as DG1). For the other DG, it can be installed in an arbitrary position among the Buses C–E (named as DG2).


(a)

(b)

Fig. 3 Voltage characteristics of the Bus-A under different locations of DG units (a) Without SFCL and (b) with the active SFCL

It shows the SFCL's overvoltage-suppressing characteristics and the waveforms with and without the SFCL are both listed.


(a)

(b)

Fig. 4 Line current waveform when the three-phase short-circuit occurs at k3 point. (a) Without SFCL and (b) with the active SFCL

It indicates the line current waveforms with and without the active SFCL when the three-phase short circuit occurs at k3 point. After installing the active SFCL, the first peak value of the fault currents (iAf, iBf, iCf) can be limited to 2.51 kA, 2.69 kA, 1.88 kA, respectively, in contrast with 3.62 kA, 3.81 kA, 2.74 kA under the condition without SFCL. The reduction rate of the expected fault currents will be 30.7%, 29.4%, 31.4%, respectively.

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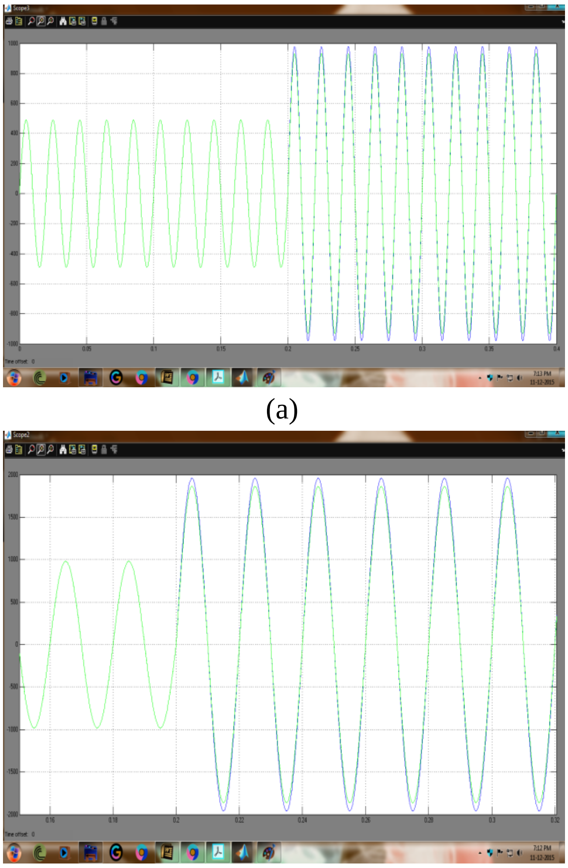

(a)

(b)

Fig. 5 Active SFCL's current-limiting performances under different fault locations (a) k1 point and (b) k2 point

The SFCL's current-limiting performances when the fault location is respectively k1 point and k2 point (selecting the phase-A current for an evaluation). Along with the decrease of the distance between the fault location and the SFCL's installation position, the current-limiting ratio will increase from 12.7% (k1 point) to 21.3% (k2 point).

IV. CONCLUSION

The application of the active SFCL into in a power distribution network with DG units is investigated. For the power frequency overvoltage caused by a single-phase grounded fault, the active SFCL can help to reduce the overvoltage's amplitude and avoid damaging the relevant distribution equipment. The active SFCL can as well suppress the short-circuit current induced by a three-phase grounded fault effectively, and the power system's safety and reliability can be improved. Moreover, along with the decrease of the distance between the fault location and the SFCL's installation position, the current-limiting performance will increase. In recently years, more and more dispersed energy sources, such as wind power and photovoltaic solar power, are installed into distribution systems. Therefore, the study of a coordinated control method for the renewable energy sources and the SFCL becomes very meaningful, and it will be performed in future.

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