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EFFECT OF FAULT CURRENT LIMITER ON DISTANCE RELAY PROTECTION

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Abstract
Transmission line protection which uses distance relays as a primary and backup is very common. Their operating principle is based on impedance interpretations at the relaying juncture, which can be affected by a number of factors like line loading prior to a fault in addition to short circuit peaks that at line end points. The network encounters a rise in short circuit levels due to the ongoing demand for electricity, which presents new difficulties. One of the suggested solutions to this issue involves the implementation of a Fault Current Limiter (FCL) that also enforces major changes mainly on measured impedance now at relaying point. The impact of hybrid superconducting fault current limiters (HSFCL) over measured impedance with distance relay so at relaying location is examined in this paper, primarily in the perspective of line to ground fault. MATLAB software is used to model a transmission system with distance relay protection and even a hybrid superconducting fault current limiter (HSFCL). MATLAB software is utilized to simulate a transmission system with distance relay protection as well as a hybrid superconducting fault current limiter (HSFCL). Both topologies of Hybrid superconducting fault current limiter (HSFCL), over distance relay protection for line to ground fault, will indeed be examined and contrasted.
Keywords: Transmission Line, Distance Protection, Apparent impedance, Fault current limiter, Impedance trajectories.

1. Introduction

Short circuit currents in power systems rise due to the ongoing increase in consumption of electrical energy. This is because more generators have been added to the power system, larger cross-section conductors have been used, and double or multi-circuit lines have been used. Short circuit current is increased, requiring larger capacity circuit breakers and increasing the exerted stress on the device. Many solutions are proposed to this problem, which include employing Fault Current Limiters (FCL) to minimize the rated capacity of circuit breakers as well as to reduce the imposed electrodynamics stress on associated equipment. In contradiction to power system variables, even when there is no fault resistance, the imposed impedance brought about by the existence of FCL may have an impact on the measured impedance. Conventional distance features are very prone to failure in the form of either over- or under-reaching the fault zone when FCL is present. As a result, in the presence of FCL, the conventional characteristics may be ineffective.

The authors in [1] provides a filter control technique to reduce harmonics and a rectification approach for the overcurrent relay using voltage components in order to use SFCL and the concept of DG in a power distribution system. The effects of SFCL installation on DG enlargement in a power system are investigated while keeping the original relay coordination. One of the key solutions regarding interconnected power system and protection is to employ a hybrid type superconducting fault current limiter [2]. The researchers in [3] offers a novel design for a Hybrid Superconducting Fault Current Limiter (Hybrid SFCL), which would be essentially made up of thyristors that are in series with just a superconducting element. The PSCAD/EMTDC programme was used to simulate the Hybrid SFCL throughout this research. The study revealed that the fault current is substantially reduced, and the proposed controller strategy performs very effectively.

The researchers in [4] provide a unique hybrid SFCL with biased magnetic field and 2-stage current limiting characteristics. The short current is limited in this type of SFCL by such a noninductive superconducting coil during the first stage and a dual-split reactor as in second stage. The experimental results showed that such current limiting ratio reaches 89.66%, validating the concept and demonstrating the hybrid SFCL's potential use.

It is suggested in the study [5] to create a power differential-based protection mechanism for appropriate detection and identification of transmission line faults underneath SFCL action. Based on normal load levels, a power differential protection strategy is constructed and trip characteristics are determined. Simulation experiments on a 220 kV transmission line confirm the efficacy of the power differential technique. Three-phase as well as single line-to-ground faults are examined. In addition, the proposed system was tested for a wide variety of SFCL resistances ranging from 10 to 500 Ω. The proposed differential protection mechanism detected faults in all test conditions.

The research [6] proposes a novel remedy for the issue of relaying maloperation that does not necessitate any changes to the relay settings. Furthermore, the results suggest that FCL can be employed as a series compensator to increase power transfer with in transmission system while it is operating normally. This avoids the need to adjust the compensated line's relay settings. As a result, the dual function of improved power transfer and reduced fault current is accomplished.

In the study [7], investigation is done about how SFCLs impact the effectiveness of travelling wave-based protection methods in high-voltage transmission lines. The results demonstrate that the SFCL attenuates the magnitudes of the travelling wave currents and that the pattern of the travelling wave is somewhat altered by the SFCL stray capacitances.

Because to the rapidly developing of the distribution network, these have short lines and many nodes. The standard three-stage current protection technique is difficult to implement and has a long fault elimination time. To address the aforementioned issues, this study [8] discusses the basic design and operation characteristics of superconducting fault current limiter, as well as a new current protection strategy based on it.

The authors in [9] investigate the effects of resistive-type SFCLs on transmission system incremental power frequency relay. The SIMULINK MATLAB programme was used to create and simulate a model of a 220 kV transmission line also with incremental power frequency relay element. Three compensatory techniques for mitigating the detrimental consequences of SFCL integration are developed and compared.

The literature review was studied and analyzed. In the survey, the influences of FCL on transmission line protection for various schemes are to be discussed. As per the previous study, the protection of transmission line gets affected at the time of current to be limited by fault current limiter. The literature survey shows the different types of fault current limiters and their effects on operation of relay for protection of transmission line. But in all these previous work, effect of fault current limiters on distance relay protection of transmission line is not discussed. In this paper the effects of Hybrid Superconducting fault current limiters on distance relay is to be analyzed. The inclusion of FCL in a fault loop will impact the voltage and current signals perceived from the relay point in both steady and fault states. As a result, the apparent impedance observed by that of the distance relay will be influenced. The effect of Hybrid superconducting fault current limiter on impedance computed by distance relay is explored in this paper. This effect is studied using the MATLAB software for single line to ground fault.

The paper is organized as follows: the operation principle and of HSFCL is presented in the next section. Section 2.2 provides the simulation studies which are performed in MATLAB software. The results obtained and discussions for Distance relay performance for Line to ground fault for both configurations of HSFCLs are explored in section 3. Finally, the conclusions remarks are given in Section 4.

2. Methodology

2.1 Operating Principle of Hybrid Superconducting Fault Current Limiter (HSFCL)

Hybrid Superconducting Fault Current Limiter (HSFCL) is a way of establishing the limiting effect by integrating the HTS element with just a fast mechanical switch, circuit breaker (CB), and power semiconductor switch. Figure 1 is a schematic representation of a Hybrid Superconducting Fault Current Limiter (HSFCL).

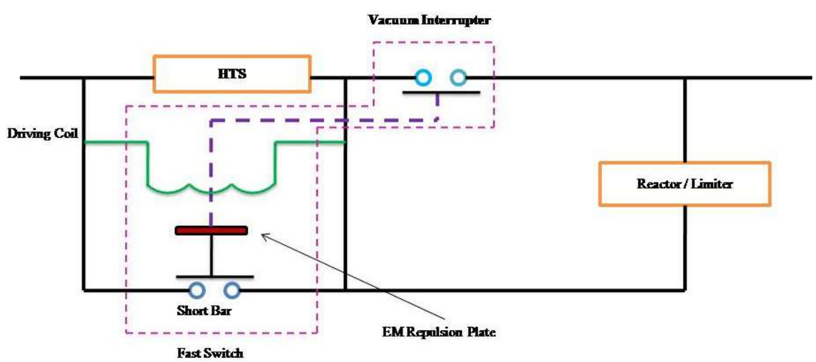

Figure 1. Schematic diagram of Hybrid SFCL Concept

The hybrid SFCL is a system used throughout electrical power systems to mitigate fault current. The most substantial change appears to occur when the superconductor never longer functions as a short circuit current delimiter, but rather as a detector for short circuit current as well as a switch that allows short circuit current to migrate towards a Current Limiting Reactor (CLR). The three basic components of hybrid SFCL are a fast switch, a current limiter (current limiting element), and a high temperature superconductor (HTS). The structure of the hybrid SFCL incorporates a fast switch, two (2) mechanical switches, a vacuum interrupter (VI), and a short bar (SB), in addition to a driving coil and even an electromagnetic plate (EM). [11].

While in use, the fast switch consists of a plunger with such a switch along either end that commutates the line current. The driving coil is primarily pulling on the repulsion plate, leading the plunger to impact and operate the limiting reactor. It should be noted that the aforementioned CLP branch (RCLP or XCLP) can be executed using either a resistive or an inductive component. This research analyses both categories employing analytical and simulation techniques.

2.3 Simulation Studies

Figure 3 depicts a power system that is used in simulation studies to investigate the impact of HSFCL upon apparent impedance observed using a distance relay. MATLAB software is used to model the HSFCL and case study. The measurement units of the relay calculate the apparent impedance.

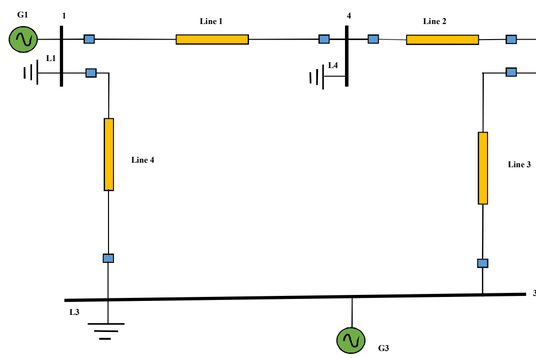

Figure 3. Case Study

3 Result and Discussions

3.1 Waveforms for current and voltage at fault location

Figures 4 and 5 show the line current in varying circumstances created by an under symmetrical fault, currently begin with line 1. Figures 5(b) and 5(c) show that RHSFCL decreases the very first cycle of fault current more efficiently than IHSFCL and may immediately reduce the DC component of fault current. The line current is found to be 4 kA at the main bus without the need for a fault current limiter throughout a symmetrical fault.

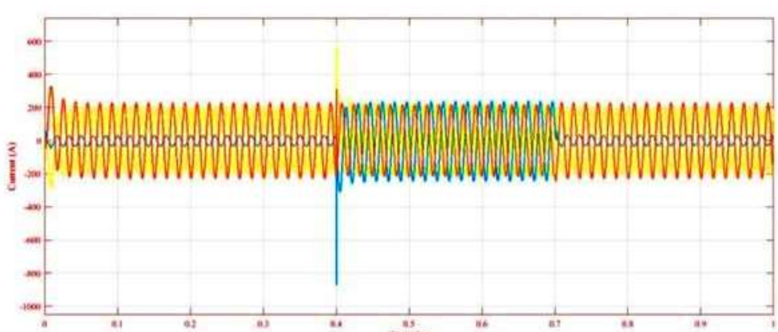

Figure 4-a. Current at fault location

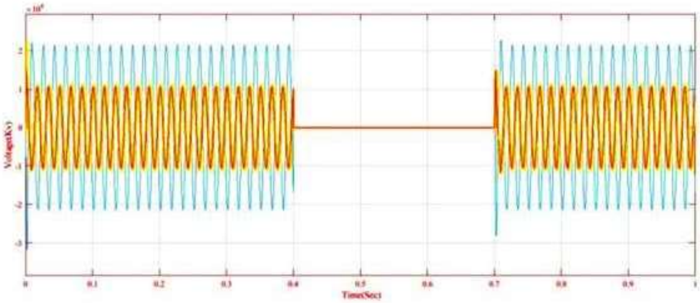

Figure 4-b. Voltage at fault location

Figure 4. Waveforms for current and voltage at fault location

When RHSFCL is used, the equivalent current is reduced to 2 kA. As shown in the illustration, the effect of IHSFCL on short circuit current is capable of being reduced to 2.1 kA. It may also be demonstrated that installing RHSFCL and IHSFCL affects the phase of certain fault current. Because when phase difference between curves is studied, it is observed that RHSFCL has a stronger effect on phase relationship than even IHSFCL.

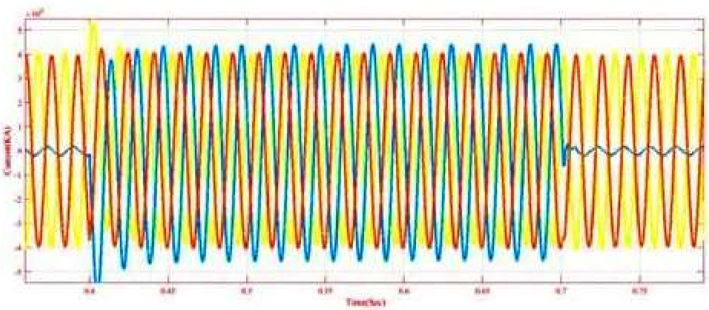

Figure 5-a. Current at main Bus without HSFCL

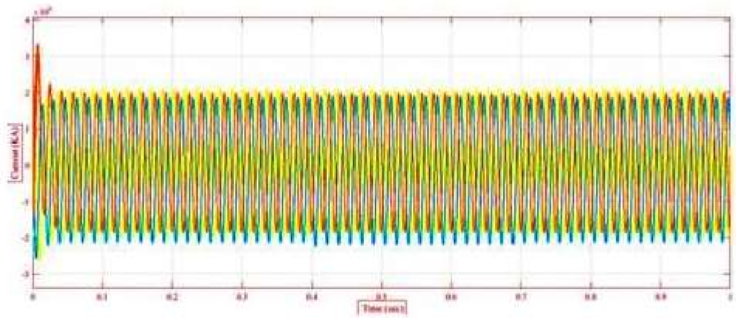

Figure 5-b. Current at main Bus with RHSFCL

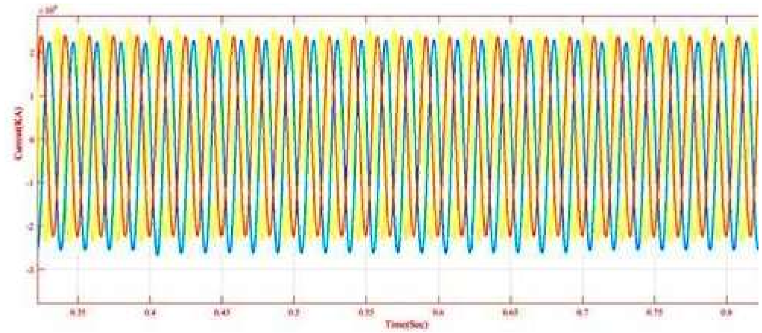

Figure 5-c. Current at main Bus with IHSFCL
Figure 5. Waveforms for current and voltage at main bus

So, in this circumstance, the significance of RHSFCL on distance relay is mainly correlated to the both the amplitude and phase of so fault current, but the influence of IHSFCL's phase on distance relay is hardly significant.

3.2. Distance Relay Performance for Line to ground fault

In this section, it must be assumed that the line to ground LG fault happens approximately 60% of line 1 as shown in figure 3. With instantaneous protection, the mho characteristic is configured to protect approximately to 80% of the line length. The impedance trajectories of instances are shown in figure 6 without HSFCL, with RHSFCL, and often with IHSFCL.
It is possible to demonstrate that the implementation of RHSFCL or IHSFCL modifies the apparent impedance by analyzing the impedance trajectories depicted in figure 6.

In this context, the overall measured impedance increased in the existence of RHSFCL and IHSFCL; however the relay currently operates efficiently. Whenever an A–G fault arises at 77 and 78 percent of line 1 or greater distance for RHSFCL and IHSFCL, accordingly, the impedance trajectories are entirely outside from mho characteristic, and also the relay is unable to detect the fault. Because the zone 1 reach limit is set to 80 percent of the line length, overall significance of these occurrences is moderate.

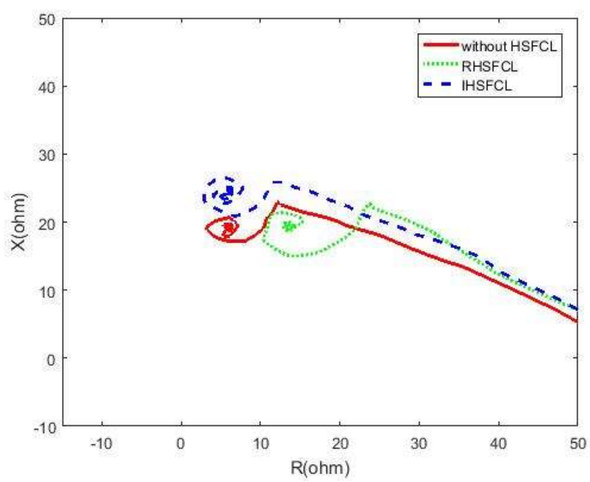

Fig.5. Impedance trajectories

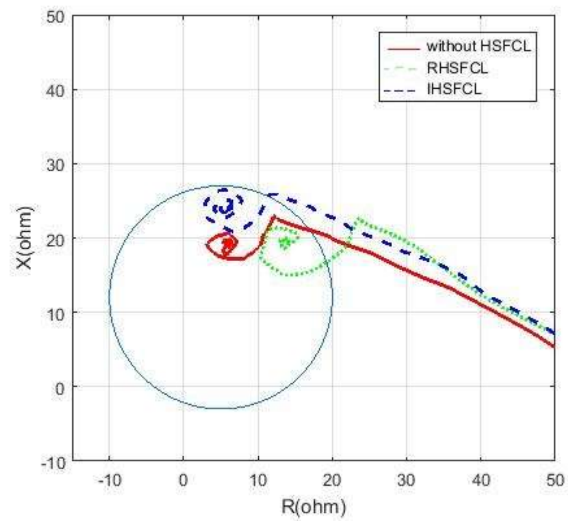

Figure 6. Impedance trajectories with distance relay characteristics

Both types of HSFCL influence apparent resistance and reactance, however the major effect of RHSFCL is dependent on apparent resistance, whereas the main effect of IHSFCL is dependent on apparent reactance.

4. Conclusions

The working principles and structures of the Hybrid superconducting fault current limiter (HSFCL) have been elaborated in detail in this paper. In the next part, the effect of HSFCL over distance relay effectiveness was investigated for single line to ground fault using both modes of HSFCL i.e. RHSFCL and IHSFCL. Across all circumstances, the results showed that these SFCLs had a detrimental influence mostly on apparent impedance seen with distance relay. In comparison, the implementation of HSFCL results in significantly underreaching for the single line to ground fault.

5. References

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