

# Compensation of Fault Current and Over voltage in a Distribution System With Renewable Distributed Generation Units Through an Active type SFCL

**k.Prabhakar reddy ,V.Pratapa Rao ,P.Padmavathi**

*Abstract*— In Today's World Electric Energy Utilization is increasing day by day ,The Utilization energy mainly in Industry, Home ,Business and Transportation ,To meet the demand Decentralizing Generating units are started .As a result there is increase in size of the generating station and inter connected network's.Due to increase in size of the Grids and Generating station also possible of abnormal operations in the system,Due to fault leads to decrease the impedance of power system network.There may be increase of current known as Fault current and based on type of fault the voltage value changes. In this paper, the influence on the voltage compensation type, active superconducting fault current limiter (ASFCL) is investigated under symmetrical and asymmetrical fault conditions. ASFCL is consisting of air-core superconducting transformers and a three-phase voltage source converter. In the normal (no fault) state the flux in air core is compensated to zero. so the ASFCL has no influence on the main circuit. Using MATLAB SIMULINK, model of the three phase AC system with ASFCL is created and control strategies test, fault current limiting test, and distance relay operation is investigated. The utilization of fault current limiters (FCLs) in powersystem provides an effective way to suppress fault currents and result in considerable saving in the investment of high capacity circuit breakers. In this work a resistive superconducting fault current limiter designed.

*Index Terms*—Distributed Generation (DG), Distribution System, Overvoltage, Short-Circuit Current, Voltage Compensation Type Active Superconducting Fault Current Limiter (SFCL).

## I. INTRODUCTION

In recent years, with the great development of interconnected power grid, the power network structure becomes increasingly complicated, and the system short circuit capacity and short circuit current have reached a new level which could exceed the allowable currents of the circuit breakers. The introduction of DG into a distribution network may bring lots of advantages, such as emergency backup and peak shaving. However, the presence of these sources will lead the distribution network to lose its radial nature, and the

fault current level will increase. when a single-phase grounded fault happens in a distribution system with isolated neutral, overvoltages will be induced on the other two healthy phases, and in consideration of the installation of multiple DG units, the impacts of the induced overvoltages on the distribution network's insulation stability and operation safety should be taken into account seriously. The increase of the fault current has imposed a severe burden on the related machinery in the grid, and the stability of the power system is also damaged. The fault current limiters (FCL) are regarded as the suitable solution to solve excessive fault current problems.

Active superconducting fault current limiter (ASFCL) voltage compensation type is a novel topology of FCL. This type SFCL not only preserves the merits of bridge type SFCL such as the automatic switch to the current limiting mode and without the quench of the superconductor, but also has the particular abilities of controlling the steady fault current and compensating active and reactive power for AC main circuit in the normal state.

In view of that the introduction of a SFCL can impact the coefficient of grounding, which is a significant contributor to control the induced overvoltage's amplitude, the change of the coefficient may bring positive effects on restraining over voltages. We have proposed a voltage compensation type active SFCL in previous work and analyzed the active SFCL's control strategy and its influence on relay protection . In addition, a 800 V/30 A laboratory prototype was made, and its working performances were confirmed well

## II. THEORETICAL ANALYSIS

### A. Structure and Principle of the Active SFCL

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.  $L_{s1}$ ,  $L_{s2}$  are the self-inductance of two superconducting windings, and  $M_s$  is the mutual inductance.  $Z_{l1}$  is the circuit impedance and  $Z_{l2}$  is the load impedance.  $L_d$  and  $C_d$  are used for filtering high order harmonics caused by the converter. Since the voltage-type converter's capability of controlling power exchange is implemented by regulating the voltage of AC side, the converter can be thought as a controlled voltage

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source Up. By neglecting the losses of the transformer, the active SFCL's equivalent circuit is shown in Fig. 1(b).

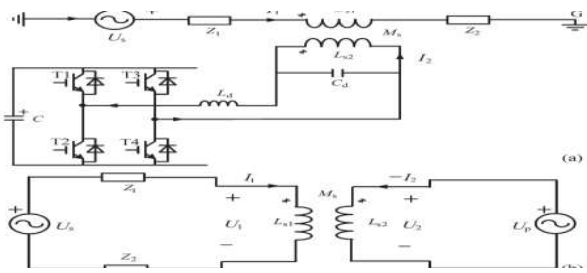


Fig. 1. Single-phase voltage compensation type active SFCL. (a) Circuit structure and (b) equivalent circuit.

In normal (no fault) state, the injected current (I2) in the secondary winding of the transformer will be controlled to keep a certain value, where the magnetic field in the air-core can be compensated to zero, so the active SFCL will have no influence on the main circuit. When the fault is detected, the injected current will be timely adjusted in amplitude or phase angle, so as to control the superconducting transformer's primary voltage which is in series with the main circuit, and further the fault current can be suppressed to some extent. Below, the suggested SFCL's specific regulating mode is explained. In normal state, the two equations can be achieved.

$$U_s = I_1(Z_1 + Z_2) + j\omega L_{s1}I_1 - j\omega M_s I_2$$

$$\dot{U}_p = j\omega M_s \dot{I}_1 - j\omega L_{s2} \dot{I}_2.$$

Controlling I2 to make  $j\omega L_{s1} \dot{I}_1 - j\omega M_s \dot{I}_2 = 0$  and the primary voltage U1 will be regulated to zero. Thereby, the equivalent limiting impedance ZSFCL is zero ( $Z_{SFCL} = U_1/I_1$ ), and I2 can be set as  $\dot{I}_2 = \dot{U}_s L_{s1}/L_{s2}/(Z_1 + Z_2)k$ , where k is the coupling coefficient and it can be shown as  $k = M_s/\sqrt{L_{s1}L_{s2}}$ . Under fault condition (Z2 is shorted), the main current will rise from I1 to If, and the primary voltage will increase to U1f.

$$\dot{I}_{1f} = (\dot{U}_s + j\omega M_s \dot{I}_2) / (Z_1 + j\omega L_{s1}) \tag{3}$$

$$\dot{U}_{1f} = j\omega L_{s1} \dot{I}_{1f} - j\omega M_s \dot{I}_2 = \dot{U}_s (j\omega L_{s1}) - \dot{I}_2 Z_1 (j\omega M_s) / (Z_1 + j\omega L_{s1}). \tag{4}$$

The current-limiting impedance ZSFCL can be controlled in:

$$Z_{SFCL} = \dot{U}_{1f} / \dot{I}_{1f} = j\omega L_{s1} - j\omega M_s \dot{I}_2 / (\dot{I}_{1f} (Z_1 + j\omega L_{s1})) = \dot{U}_s + j\omega M_s \dot{I}_2 / \dot{I}_{1f} (Z_1 + j\omega L_{s1}). \tag{5}$$

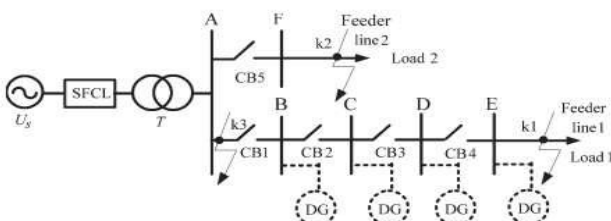


Fig. 2. Application of the active SFCL in a distribution system with DG units.

According to the difference in the regulating objectives of I2, there are three operation modes:

- 1) Making I2 remain the original state, and the limiting impedance  $Z_{SFCL-1} = Z_2 (j\omega L_{s1}) / (Z_1 + Z_2 + j\omega L_{s1})$ .
- 2) Controlling I2 to zero, and  $Z_{SFCL-2} = j\omega L_{s1}$ .
- 3) Regulating the phase angle of I2 to make the angle difference between Us and  $j\omega M_s I_2$  be 180°. By setting  $j\omega M_s I_2 = -c U_s$ , and  $Z_{SFCL-3} = c Z_1 / (1-c) + j\omega L_{s1} / (1-c)$ .

The air-core superconducting transformer has many merits, such as absence of iron losses and magnetic saturation, and it has more possibility of reduction in size, weight and harmonic than the conventional iron-core superconducting transformer. Compared to the iron-core, the air-core can be more suitable for functioning as a shunt reactor because of the large magnetizing current, and it can also be applied in an inductive pulsed power supply to decrease energy loss for larger pulsed current and higher energy transfer efficiency. There is no existence of transformer saturation in the air-core, and using it can ensure the linearity of ZSFCL well.

### B. Applying the SFCL into A Distribution Network

with DG

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. 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. In order to calculate the over voltages induced in the other two phases (phase B and phase C), the symmetrical component method and complex sequence networks can be used, and the coefficient of grounding G under this condition can be expressed as  $G = -1.5m / (2 + m) \pm j\sqrt{3}/2$ , where  $m = X_0/X_1$ , and X0 is the distribution network's zero-sequence reactance, X1 is the positive-sequence reactance [6]. Further, the amplitudes of the B-phase and C-phase over voltages can be described as:

$$U_{BO} = U_{CO} = \sqrt{3} \left| \frac{\sqrt{G^2 + G + 1}}{G + 2} \right| U_{AN}$$

Where UAN is the phase-to-ground voltage's root mean square (RMS) under normal condition.

### C. SUPERCONDUCTING FAULT CURRENT LIMITER

Superconducting Fault Current Limiter (SFCL) is innovative electric equipment which has the capability to reduce the fault current level within the first cycle of fault current [1]. The first-cycle suppression of fault current by a SFCL results in an increased transient stability of the power system carrying higher power with greater stability. 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. The term “quench” is commonly used to describe the propagation of the normal zone through a superconductor. Once initiated, the quench process is often rapid and uncontrolled. Though once initiated the quench process is uncontrolled, the extent of the normal region and the temperature rise in the materials can be predicted.

### III. MATLAB/SIMULINK RESULTS

For purpose of quantitatively evaluating the current-limiting and overvoltage-suppressing characteristics of the active SFCL, the distribution system with DG units and the SFCL for the other DG, it can be installed in an arbitrary position among the Buses C–E (named as DG2). To reduce the converter’s design capacity, making the SFCL switch to the mode 2 after the fault is detected, and the detection method is based on measuring the main current’s different components by Fast Fourier Transform (FFT) and harmonic analysis.

Case: 1 Without SFCL and with the active SFCL

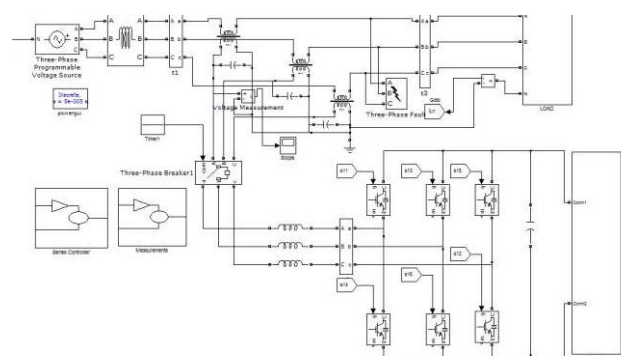


Fig. 3. Matlab/Simulink Model of Three Phase Short-Circuit Occurs A K3 Point. Without SFCL and With the Active SFCL.

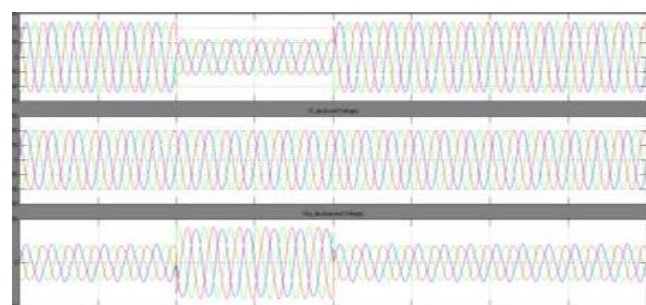


Fig. 4. Voltage Waveforms When The Three-Phase Short-Circuit Occurs A K3 Point. Without SFCL and With the Active SFCL.

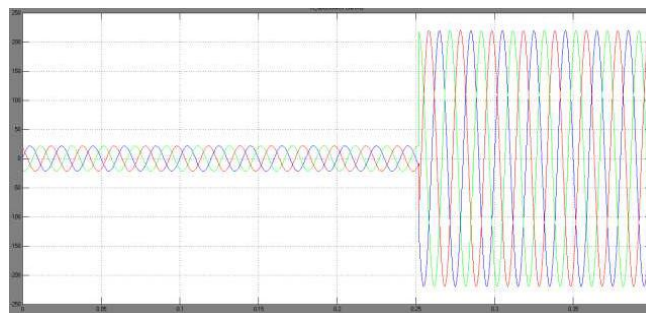


Fig. 5 Line Current Waveforms When The Three-Phase Short-Circuit Occurs A K3 Point.

Case: 2 Without SFCL and with the active SFCL with pv

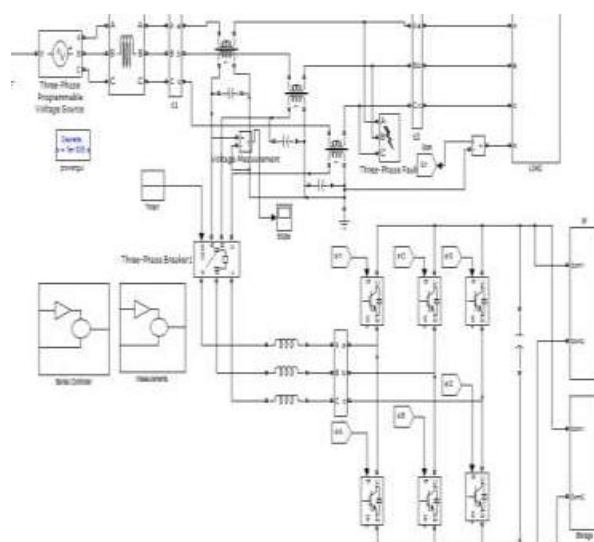


Fig. 6. Matlab/Simulink Model of Three Phase Short-Circuit Occurs A K3 Point. Without SFCL and With the Active SFCL with PV

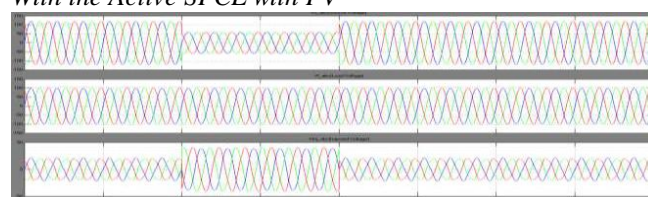


Fig. 7. Voltage Waveforms When The Three-Phase Short-Circuit Occurs A K3 Point. Without SFCL And With The Active SFCL With PV.

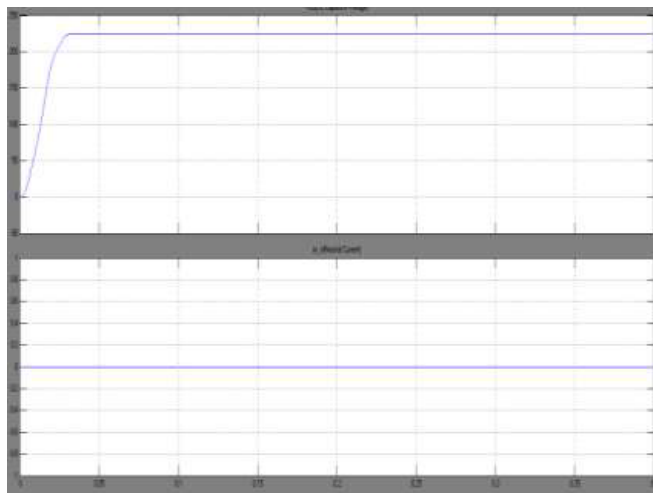


Fig. 8. Photovoltaic Voltage

Figure 8 shows Without SFCL and with the active SFCL with photovoltaic voltage.

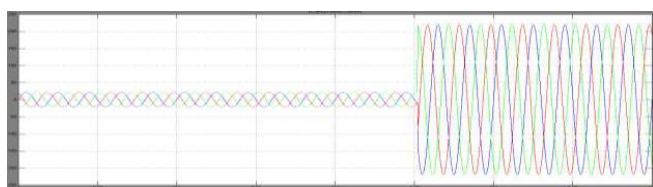


Fig. 9 Line Current Waveforms When the Three-Phase Short-Circuit Occurs A K3 Point with PV

#### IV. CONCLUSION

In this paper, 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. 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. *in recent* years ,more and more dispersed energy 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 m

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