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Reduce the Surge Current Error Caused the Distribution System Generation SFCL

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ABSTRACT

The main aim of project is to tranquilize of the current and voltage under abnormal conditions in distribution system by using active type super conducting fault current limiter. 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 faults 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 power system provides an effective way to suppress fault currents and result in considerable saving in the investment of high capacity circuit breakers.

Index Terms: *Active type super conducting fault current limiter (ASFCL), Distribution system, Over voltage, Short circuit current, Air core super conducting transformer, Voltage source converter*

I.INTRODUCTION

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 power system provides an effective way to suppress fault currents and result in considerable saving in the investment of high capacity circuit breakers. fault current level will increase. When a single-phase grounded fault happens in a distribution system with isolated neutral, over voltages will be induced on the other two health phases, and in consideration of the installation of multiple DG units, the impacts of the induced over voltages 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.

II. ANALYSIS OF SUPERCONDUCTING FAULT CURRENT LIMITER (SFCL)

A. *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.

B. *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.Ls1, Ls2 are the self-inductance of two superconducting windings, and Ms is the mutual inductance.Z1is the circuit impedance andZ2is the load impedance. Ld and Cd 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 source Up. By neglecting the losses of the transformer, the active SFCL's equivalent circuit is shown in Fig. 1(b).

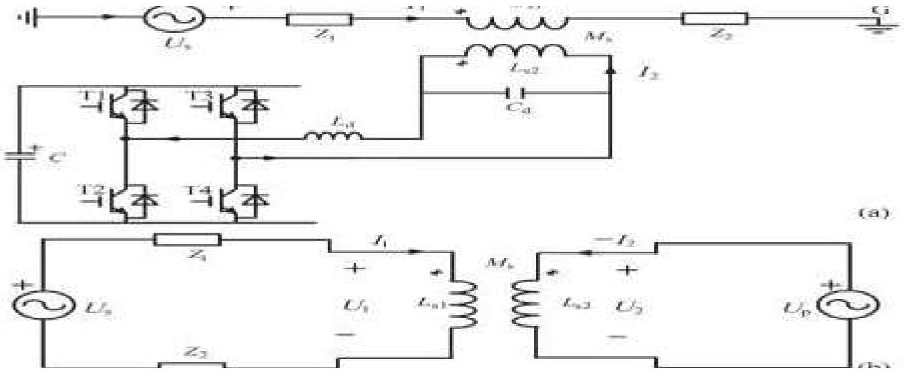


Fig. 1. Single-phase voltage compensation type active SFCL. (a) Circuit structure and (b) equivalent circuit.

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.

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

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

Controlling *I*2 to make j*ωLs*1 *İ*1 − j*ωMs İ*2 = 0 and the primary voltage *U*1 will be regulated to zero. Thereby, the equivalent limiting impedance *Z*SFCL is zero (*Z*SFCL = *U*1/*I*1), and *I*2 can be set as ˙ *I*2 = ˙*Us_Ls*1/*Ls*2/(*Z*1 + *Z*2)*k*, where *k* is the coupling coefficient and it can be shown as *k* = *Ms*/ √*Ls*1 *Ls*2.Under fault condition (*Z*2 is shorted), the main current will rise from *I*1 to *I*1f , and the primary voltage will increase to *U*1f .

*İ*1*f*=(˙*Us* + j*ωMs İ*2)/(*Z*1 + j*ωLs*1)

˙*U*1*f*=j*ωLs*1 *İ*1*f*− j*ωMs İ*2

=˙*Us*(j*ωLs*1) − *İ*2*Z*1(j*ωMs*)*Z*1 + j*ωLs*1.

The current-limiting impedance *Z*SFCL can be controlled in:

ZSFCL =˙*U*1*fİ*1*f*= j*ωLs*1 − j*ωMsİ*2(*Z*1+j*ωLs*1)˙*Us*+j*ωMİ a*.

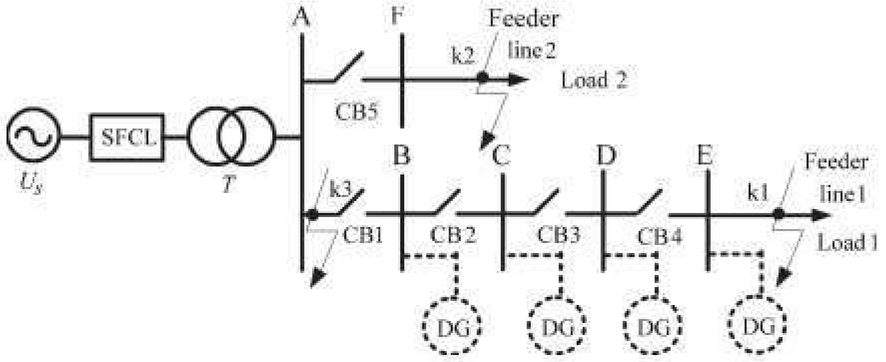


Fig. 2. Application of the active SFCL in a distribution system with DG units.

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

1) MakingI2 remain the original state, and the limiting impedanceZSFCL−1=Z2 (jωLs1)/(Z1+Z2+jωLs1).

2) ControllingI2to zero, andZSFCL−2=jωLs1.

3) Regulating the phase angle of I2 to make the angle difference between˙ Us and jωMs˙I2 be 180◦.Bysetting

jωMs I2=−c˙Us, and ZSFCL−3=cZ1/(1−c)+jωLs1/(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.

C. *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)±j√3/2, where m=X0/X1, and X0 is the distribution network'szero-sequencereactance,X1is 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.

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 and the SFCL 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). The model's main parameters are shown in Table I. 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.

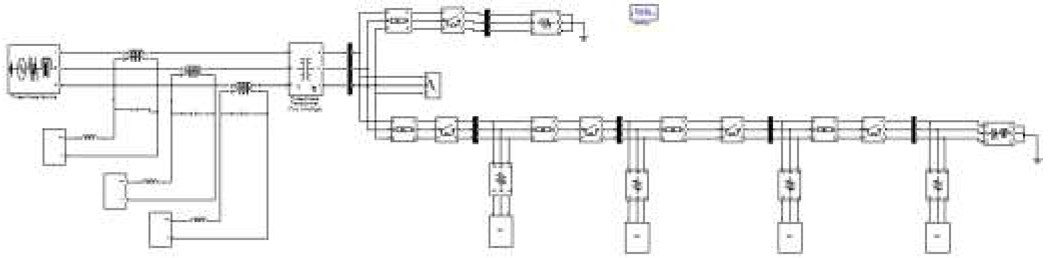


FIG 3.SIMULINK MODEL THE ACTIVE SFCL IN A DISTRIBUTION SYSTEM WITH DG UNITS

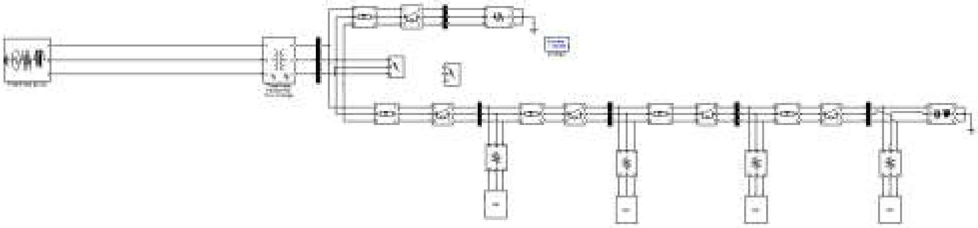


FIG 4. SIMULINK MODEL WITHOUT ACTIVE SFCL IN A DISTRIBUTION SYSTEM WITH DG UNITS

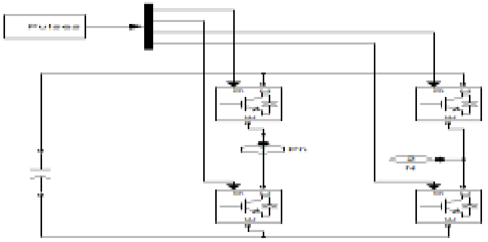


FIG 5. SIMULINK MODEL OF INTERNAL CIRCUIT OF AN ACTIVE TYPE SFCL

Overvoltage-Suppressing Characteristics of the SFCL

Supposing that the injection capacity of each DG is about 80% of the load capacity (load 1), and the fault location is k1 point (phase-A is shorted), and the fault time is *t* = 0.2 s, the simulation is done when the DG2 is respectively installed in the Buses C, D, and E, and the three cases are named as case I, II, and III. Fig. 4 shows the SFCL's overvoltage-suppressing Characteristics and the waveforms with and without the SFCL are both listed. For the cases I, II, and III, the overvoltage's peak amplitude without SFCL will be respectively 1.14, 1.23, 1.29 times of normal value, and once the active SFCL is applied, the corresponding times will drop to 1.08, 1.17, and 1.2.

During the study of the influence of the DG's injection capacity on the overvoltage's amplitude, it is assumed that the adjustable range of each DG unit's injection capacity is about 70% and 100% of the load capacity (load 1), the two DG units are located in the Buses B and E, and the other fault conditions are unchanged, Table II shows the overvoltage's amplitude characteristics under this background. Along with the increase of the DG's injection capacity, the overvoltage will be accordingly rise, and once the injection Capacity is equal or greater than 90% of the load capacity, the overvoltage will exceed acceptable limit (1.3 times). Nevertheless, if the active SFCL is put into use, the limit-exceeding problem can be solved effectively.

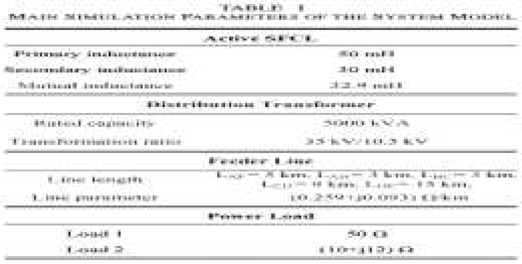


TABLE I
MAIN SIMULATION PARAMETERS OF THE SYSTEM MODEL

Active SFCL	
Primary inductance	50 mH
Secondary inductance	30 mH
Mutual inductance	32.9 mH
Distribution Transformer	
Rated capacity	5000 kVA
Transformation ratio	35 kV/10.5 kV
Feeder Line	
Line length	[illegible]
Line parameter	(0.259+j0.093) Ω/km
Power Load	
Load 1	50 Ω
Load 2	(10+j12) Ω

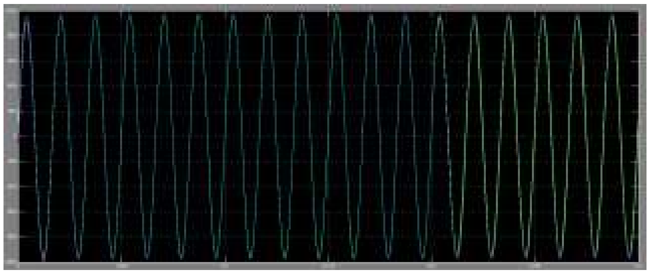
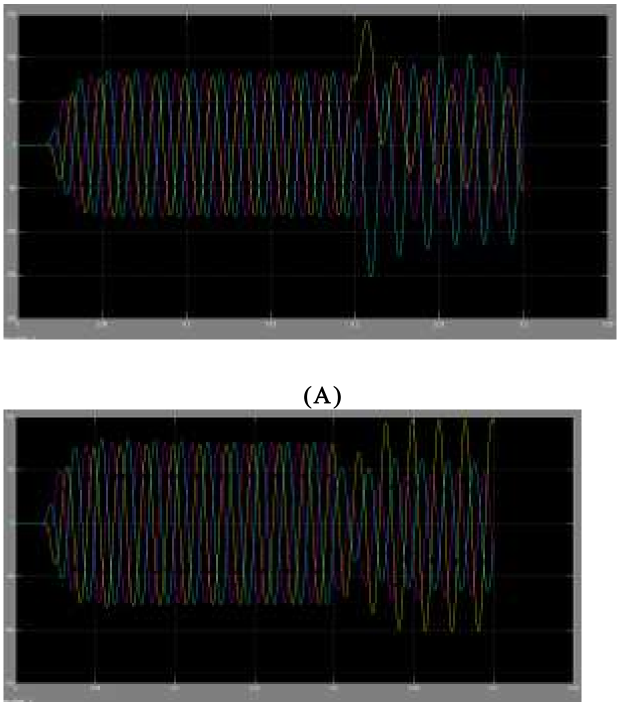


FIG 6 VOLTAGECHARACTERISTICS OF THE BUS-A UNDER DIFFERENT LOCATIONS OF DG UNITS WITHOUT SFCL AND WITH THE ACTIVE SFCL

TABLE II
OVERVOLTAGE'S AMPLITUDE CHARACTERISTICS UNDER DIFFERENT INJECTION CAPACITIES OF DG UNITS

DG's injection capacity	Ratio of overvoltage to normal voltage	
	Without SFCL	With the active SFCL
70%	1.25	1.19
80%	1.29	1.2
90%	1.33	1.22
100%	1.38	1.29



(A)

(B)

FIG 7. LINE CURRENT WAVEFORMS WHEN THE THREE-PHASE SHORT-CIRCUIT OCCUR AT K3 POINT. (A) WITHOUT SFCL AND (B) WITH THE ACTIVE SFCL.

Current-Limiting Characteristics of the SFCL

By observing the voltage compensation type active SFCL's installation location, it can be found out that this device's current-limiting function should mainly reflect in suppressing the line current through the distribution transformer. Thereupon, to estimate the most serious fault characteristics, the following conditions are designed: the injection capacity of each DG is about 100% of the load capacity (load 1), and the two DG units are separately installed in the Buses B and E. Moreover, the three-phase fault occurs at k1, k2, and k3 points respectively, and the fault occurring time is $t = 0.2$ s. Hereby, the line current characteristics are imitated. As shown in Fig.

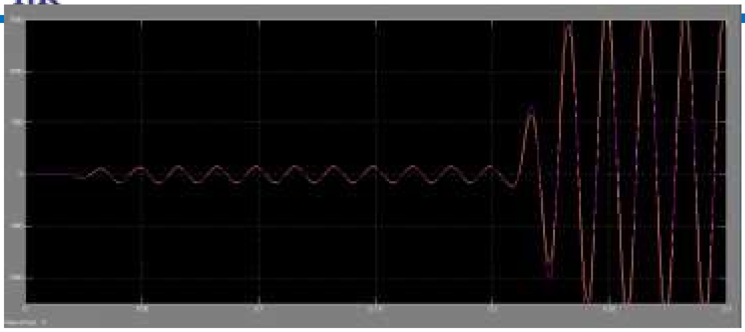


FIG 8. ACTIVE SFCL'S CURRENT-LIMITING PERFORMANCES UNDER DIFFERENT FAULT LOCATIONS.(A) K2 POINT

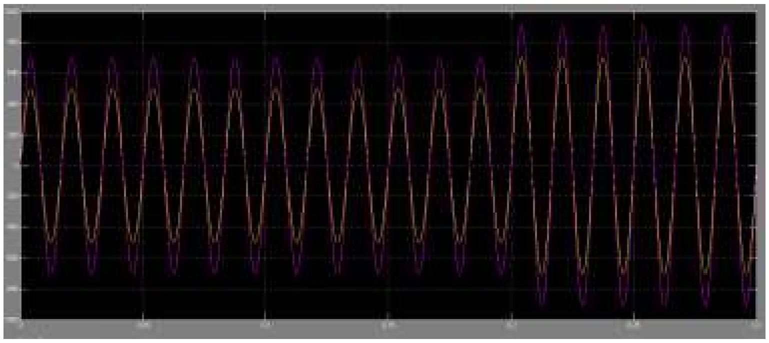


FIG 9. ACTIVE SFCL'S CURRENT-LIMITING PERFORMANCES UNDER DIFFERENT FAULT LOCATIONS.(B) K1 POINT.

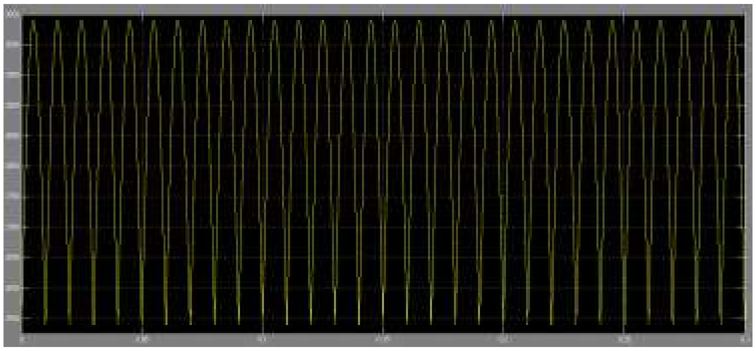


FIG 10.INFLUENCE OF INITIAL FAULT ANGLE ON PEAK AMPLITUDE OF THE A-PHASE SHORT-CIRCUIT CURRENT WITHOUT SFCL

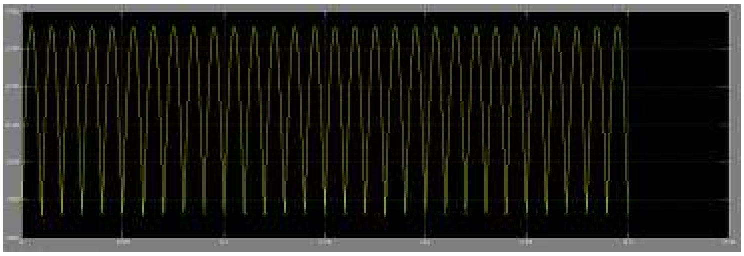


FIG 11. INFLUENCE OF INITIAL FAULT ANGLE ON PEAK AMPLITUDE OF THE A-PHASE SHORT-CIRCUIT CURRENT WITH SFCL

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). Besides, as one component of fault current, natural response is an exponential decay DC wave, and its initial value has a direct relationship with fault angle. Through the application f the active SFCL, the influence of initial fault angle on the peak amplitude of the A-phase short-circuit current is analyzed in Fig. where the fault location is k3 point. It can be seen that, under the conditions with and without the SFCL, the short circuit Current's peak amplitude will be smallest when the fault angle is about 130◦. At this fault angle, the power distribution system can immediately achieve the steady transition from Normal state to fault state.

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 sources, such as wind power and photovoltaic solar power , are installed into distribution systems.

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