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Aircraft Electrical Power Generation & Distribution System Units Through an Active Type SFCL

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ABSTRACT

This paper illustrates a generic Electrical Power Generation & Distribution System. The AC power frequency is variable and depends of the engine speed. The represents the generator mechanical drive and is modeled by a simple signal builder, which provides the mechanical speed of the engine shaft.The represents the power AC generator. It is composed of a modified version of the simplified synchronous machine. The mechanical input of the modified machine of 50 kW is the engine speed. The Generator Control Unit regulates the voltage of the generator to 200 volts line to line.The represents the Primary Distribution system. It is composed of three current and voltage sensors. There is also a 3-phase contactor controlled by the Generator Control Unit. Finally, a parasitic resistive load is required to avoid numerical oscillations. The section represents the secondary Power Distribution system. It is represented by 4 circuit breakers with adjustable current trip. The section represents the AC loads. There is a 4 kW Transformer and Rectifier Unit (which supplies 28 Vdc), a 12 kW induction machine (motor driving a pump), a 1 kW resistive load (lamps) and a 3 hp simplified (using an average value inverter) brushless DC drive (motor driving a ballscrew actuator)

I. INTRODUCTION

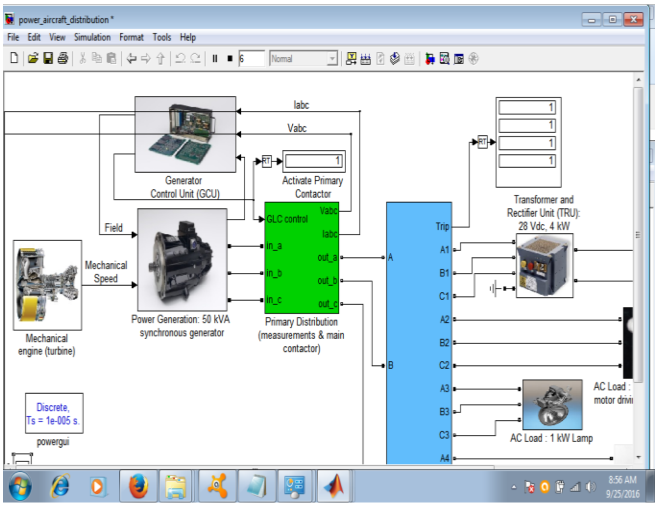
Due to increased consumption demand and high cost of natural gas and oil, distributed generation (DG), which Generates electricity from many small energy sources, is becoming one of main components in distribution systems to feed electrical loads [1]–[3]. The introduction of DG into a distribution network 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. Besides, 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 overvoltages on the distribution network's insulation stability and operation safety should be taken into account seriously. Aiming at the mentioned technical problems, applying superconducting fault current limiter (SFCL) may be a feasible solution. For the application of some type of SFCL into a distribution network with DG units, a few works have been carried out, and their research scopes mainly focus on current-limitation and improvement of protection coordination of protective devices[4]–[6]. Nevertheless, with regard to using a SFCL for suppressing the induced overvoltage, the study about it is relatively less. 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 overvoltage. We have proposed voltage compensation type active SFCL in previous work [7], and analyzed the active SFCL's control strategy and its influence on relay protection [8]. In addition, a 800 V/30 A laboratory prototype was made, and its working performances were confirmed well [7]. In this paper, taking the active SFCL as an evaluation object, its effects on the fault current and overvoltage in a distribution network with multiple DG units are studied. In view of the changes in the locations of the DG units connected into the distribution system, the DGunits' injection capacities and the fault positions, the current limiting and overvoltage-suppressing characteristics of the active SFCL are investigated in detail.

II. THEORETICAL ANALYSIS

A. Structure and Principle of the Active SFCL

As shown in Fig. 1(a), it denotes the circuit structure of thesingle-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. $Z1$ is the circuit impedance and $Z2$ is 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).



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.

$$\dot{U}_s = \dot{I}_1(Z_1 + Z_2) + \mathrm{j}\omega L_{s1}\dot{I}_1 - \mathrm{j}\omega M_s\dot{I}_2 \qquad (1)$$

$$\dot{U}_p = \mathrm{j}\omega M_s\dot{I}_1 - \mathrm{j}\omega L_{s2}\dot{I}_2. \qquad (2)$$

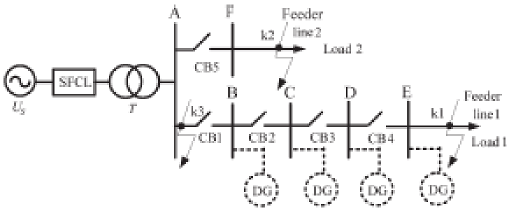


Fig. 2. Application of the active SFCL in a distribution system with DG units.

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 $ZSFCL-1 = Z2(j\omega Ls1)/(Z1 + Z2 + j\omega Ls1)$.

2) Controlling $I2$ to zero, and $ZSFCL-2 = j\omega Ls1$.

3) Regulating the phase angle of $I2$ to make the angle difference between $\dot{U}s$ and $j\omega Ms\,\dot{I}2$ be 180◦. By setting $j\omega Ms\,\dot{I}2 = -c\,\dot{U}s$, and $ZSFCL-3 = cZ1/(1 - c) + j\omega Ls1/(1 - c)$.

The air-core superconducting transformer has many merits, such as absence of iron losses and magnetic saturation, and ithas more possibility of reduction in size, weight and harmonic than the conventional iron-core superconducting transformer [6], [2]. Compared to the iron-core, the air-core can be more suitable for functioning as a shunt reactor because of the large magnetizing current [3], 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 [4], [5].There is no existence of transformer saturation in the air-core,and using it can ensure the linearity of $ZSFCL$ well.

III. SIMULATION STUDY

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, 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 anarbitrary 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 [1], 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.

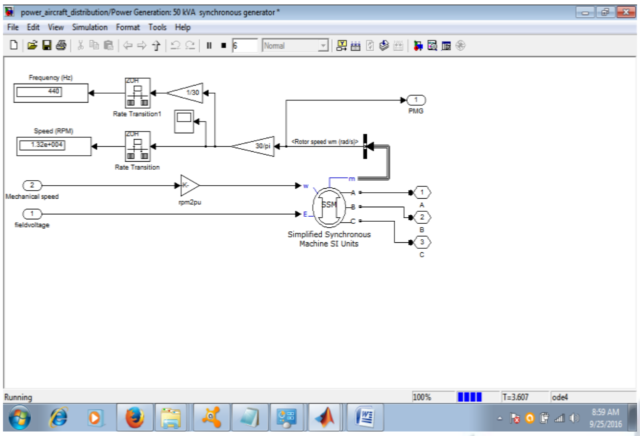


Fig3: power generation circuit

A.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

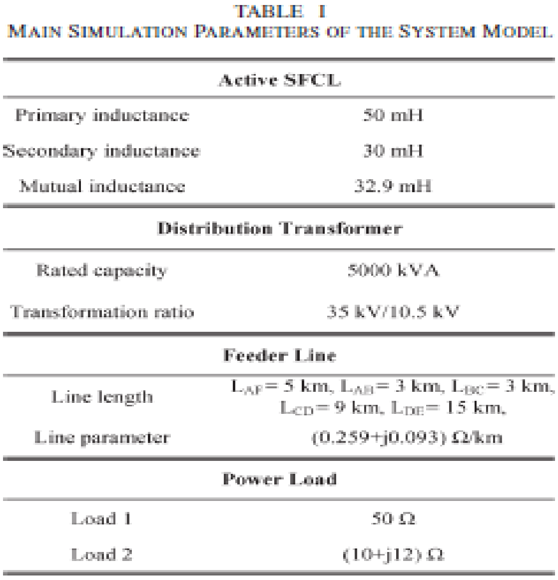


TABLE I

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	L_{AF}= 5 km, L_{AB}= 3 km, L_{BC}= 3 km, L_{CD}= 9 km, L_{DE}= 15 km,
Line parameter	(0.259+j0.093) Ω/km
Power Load	
Load 1	50 Ω
Load 2	(10+j12) Ω

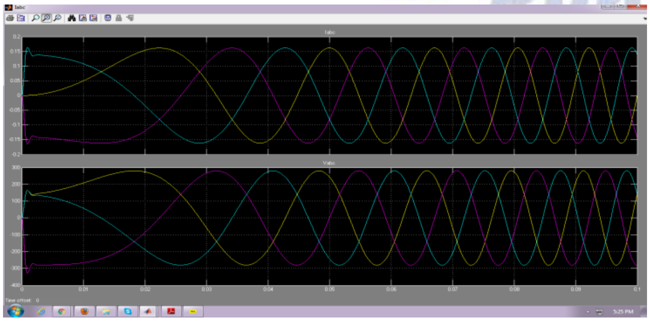


Fig4: primary simulation output

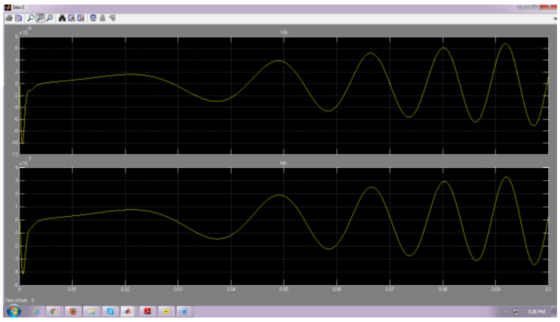


Fig5: secondary simulation output

Are both listed? For the cases I, II, and III, the overvoltage's peak amplitude without SFCL will be respectively 1.14, 1.23, 1.29times 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 about70% ~ 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.

B. Load Characteristics of the SFCL

By observing the voltage compensation type active SFCL'sinstallation 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. 5, 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. Fig. 6 shows 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). 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. In other words, corresponding to different initial fault angles, the short-circuit current's peak amplitudes will be distinguishing. Through the application and load simulation

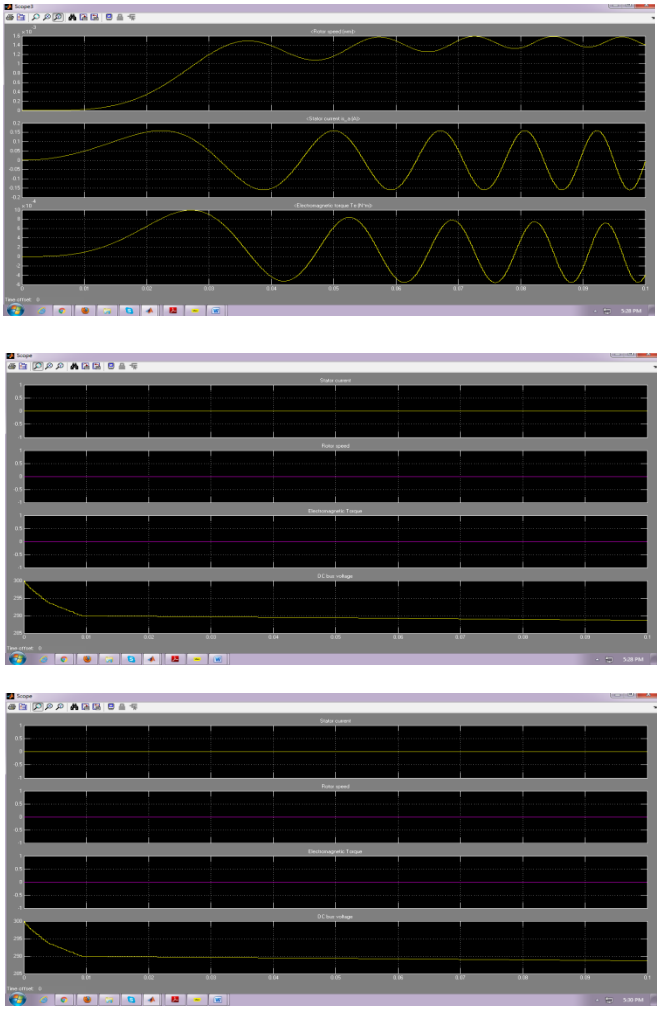


FIG6 :LOAD simulation outputs

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. 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.

REFERENCES

[1] S. Conti, "Analysis of distribution network protection issues in presence of dispersed generation," *Elect. Power Syst. Res.*, vol. 79, no. 1, pp. 49–56,Jan. 2009.

[2] A. S. Emhemed, R. M. Tumilty, N. K. Singh, G. M. Burt, and J. R. McDonald, "Analysis of transient stability enhancement of LVconnected induction microgenerators by using resistive-type fault current limiters," *IEEE Trans. Power Syst.*, vol. 25, no. 2, pp. 885–893, May 2010.

[3] S.-Y. Kim and J.-O. Kim, "Reliability evaluation of distribution network with DG considering the reliability of protective devices affected by SFCL," *IEEE Trans. Appl. Supercond.*, vol. 21, no. 5, pp. 3561–3569, Oct. 2011.

[4] S. Hemmati and J. Sadeh, "Applying superconductive fault current limiterto minimize the impacts of distributed generation on the distribution protectionsystems," in *Proc. Int. Conf. Environ. Electr. Eng.*, Venice, Italy,May 2012, pp. 808–813.

[5] L. Chen, Y. Tang, J. Shi, and Z. Sun, "Simulations and experimentalanalyses of the active superconducting fault current limiter," *Phys. C*,vol. 459, no. 1/2, pp. 27–32, Aug. 2007.

[6] L. Chen, Y. Tang, J. Shi, Z. Li, L. Ren, and S. Cheng, "Control strategyfor three-phase four-wire PWM converter of integrated voltage compensationtype active SFCL," *Phys. C*, vol. 470, no. 3, pp. 231–23 Feb. 2010.

[7] L. Chen, Y. J. Tang, J. Shi, L. Ren, M. Song, S. J. Cheng, Y. Hu, andX. S. Chen, "Effects of a voltage compensation type active superconducting fault current limiter on distance relay protection," *Phys. C*, vol. 470,no. 20, pp. 1662–1665, Nov. 2010.

[8] J. Wang, L. Zhou, J. Shi, and Y. Tang, "Experimental investigation of anactive superconducting current controller," *IEEE Trans. Appl. Supercond.*,vol. 21, no. 3, pp. 1258–1262, Jun. 2011.