ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

Cat Swarm Optimization Based Solid State Faultcurrent Limiter In Distribution System

Jafar. M, Naderi S.B, TarafdarHag.M, Abapour.M, and Hossein S.H

ABSTRACT

This project proposes a modified bridge type flux-coupling non-superconducting fault current limiter (BSFC-NSFCL) for suppressing the fault current. A flux-coupling reactor and a bidirectional bridge switch are combined to perform the functions of steady-state line current sharing and fault current suppression. The proposed system is addressing a new and modern optimization tool such as cat swarm optimization (CSO) algorithm. It is generated by observing the behaviors of cats, and composed of two sub-models, i.e., tracing mode and seeking mode, which model upon the behaviors of cats. The modified CSO based BSFC-NSFCL mainly utilizes the magnetic flux cancellation effect to make the limiter behave as a short circuit on the circuit during normal operation. Hence, there is almost no impact on the power system when the limiter is used. When a fault event occurs, the bridge switch turns off immediately, and then the magnetic flux cancellation effect disappears. Thus, the impedance of primary coil inserts into the circuit to restrict the fault current phenomena. Once the fault is removed, the bridge switch turns on again, and the BSFC-NSFCL recovers to the normal operation.

1 Introduction

In today circumstances ,rapid development of power network cause the fault current of the system increased greatly. The levels of fault current in many places have often exceeded the withstand capacity of existing power system equipment. As implication to this matter; security, stability ,andreliability of power system will be negatively affected. Thus, limiting the fault current of the power system to a safe level can greatly reduce the risk of failure to the power system equipment due to high fault current flowing through the system. Because of that,there is no surprise to fault current limiting technology has become a hotspot of fault protection research since this technology can limit the fault curren toalowlevel. In power system design view, limiting the fault current to alow level can reduce the design capacity of some electricalequipment in the power system. This will lead to the reduction to the investment cost for high capacity circuitbreakersand construction of new transmission line. Consequently, from both technical and economical points of view, fault current limiting technology for reducing short circuit current is needed.

2.Fault current limiter

$$P_{loss} = R_p i_{Lp,\mathrm{rms}}^2 + R_s i_{Ls,\mathrm{rms}}^2 + \frac{2 i_{Ls,\mathrm{peak}}}{\pi}(V_{sw} + 2V_{DF}), \qquad (1)$$

Where iLp,rms and iLs,rms are the rms values of the flux-coupling reactor's primary and secondary steady-state currents, respectively, iLs,peak is the maximum value of the flux-couplingreactor's secondary steady-state current, RP and RS are given.

$$\alpha = \frac{3\times P_{loss}}{3\times P_{load}} = \frac{R_p i_{Lp,\mathrm{rms}}^2 + R_s i_{Ls,\mathrm{rms}}^2 + \frac{2 i_{Ls,\mathrm{peak}}}{\pi}(V_{sw} + 2V_{DF})}{i_{line,\mathrm{rms}}^2 \times R_{load}}, \quad (2)$$

The operation principle of the BSFC-NSFCL can be divided into two states, depicted as follows.

1) Normal state:

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

During this state, the line current separately flows through the primary and secondary windings of the flux-coupling reactor. The circuit diagram of this state is demonstrated as Figs. 3(a) and 3(b), respectively. During this state, the IGBT turns on, and the diode strings D1 and D4 and D2 and D3 conduct, alternatively. Therefore, the bridge switch allows the secondary current to flow through the secondary winding of the flux-coupling reactor bi-directionally. Since the primary and secondary coils of the BSFC-NSFCL are wound in an opposite and concentric arrangement, it is magnetically coupled in this state, and the fluxes resulted from the primary and secondary coils counteract each other. Thus, the voltage across the flux-coupling reactor is nearly zero. The turns of the flux-coupling reactor's primary side is less than its secondary side so that it can ensure that less line current flows through the bridge switch. The turn's ratio Np/Ns is 1/n, where Np and Ns are the number of turns in the flux-coupling reactor's primary and secondary coils, respectively. This design purpose is mainly to achieve the current sharing function so that the power loss of the bridge switch can be reduced. Moreover, if the bridge switch fails, the flux-coupling reactor will still remain in the circuit and acts as a reactor. As long as the impedance of the flux-coupling reactor's primary coil is designed to be capable to limit the fault current to the expected value and to make the load voltage maintain an acceptable level, there is almost no reliability issue for installing the BSFC-NSFCL in the distribution power network. During this state, the voltage across the BSFC-NSFCL is small enough to be negligible, so there is almost no influence on the circuit when the BSFC-NSFCL is installed.

2) Fault state

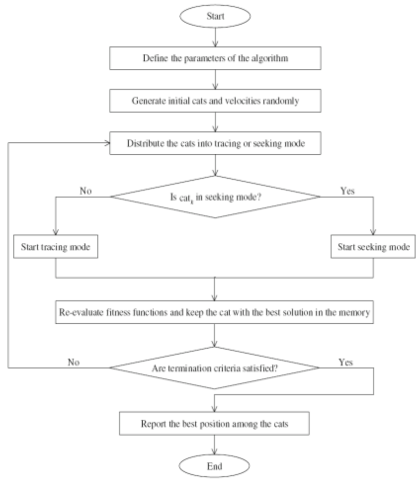
When a fault event occurs at the downstream of the BSFC-NSFCL, the current detection and control circuit detects the fault current and then turns off the bridge switch. The secondary side of the flux-coupling reactor is open-circuited, and the fault current will totally flow through the primary side of the flux-coupling reactor. Since the primary inductance of the flux-coupling reactor can restrain the fault current to the expected fault current value. After the fault is cleared, the BSFC-NSFCL will fast recover to the normal state and be ready for the next short-circuit fault occurrence.

3. Natural Process of the Cat Swarm Optimization Algorithm

Despite spending most of their time in resting, cats have high alertness and curiosity about their surroundings and moving objects in their environment. This behavior helps cats in finding preys and hunting them down. Compared to the time dedicated to their resting, they spend too little time on chasing preys to conserve their energy.

Inspired by this hunting pattern, Chu and Tsai (2007) developed CSO with two modes: "seeking mode" for when cats are resting and "tracing mode" for when they are chasing their prey. In CSO, a population of cats are created and randomly distributed in the M-dimensional solution space, with each cat representing a solution. This population is divided into two subgroups. The cats in the first subgroup are resting and keeping an eye on their surroundings (i.e., seeking mode), while the cats in the second subgroup start moving around and chasing their preys (i.e., tracing mode). The mixture of these two modes helps CSO to move toward the global solution in the M-dimensional solution space. Since the cats spend too little time in the tracing mode, the number of the cats in the tracing subgroup should be small. This number is defined by using the mixture ratio (MR) which has a small value. After sorting the cats into these two modes, new positions and fitness functions will be available, from which the cat with the best solution will be saved in the memory. These steps are repeated until the stopping criteria are satisfied.

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019



4.Seeking Mode (Resting)

During this mode the cat is resting while keeping an eye on its environment. In case of sensing a prey or danger, the cat decides its next move. If the cat decides to move, it does that slowly and cautiously. Just like while resting, in the seeking mode the cat observes into the M-dimensional solution space in order to decide its next move. In this situation, the cat is aware of its own situation, its environment, and the choices it can make for its movement. These are represented in the CSO algorithm by using four parameters: seeking memory pool (SMP), seeking range of the selected dimension (SRD), counts of dimension to change (CDC), and self-position consideration (SPC). SMP is the number of the copies made of each cat in the seeking process. SRD is the maximum difference between the new and old values in the dimension selected for mutation. CDC tells how many dimensions will be mutated. All these parameters define the seeking process of the algorithm. SPC is the Boolean variable which indicates the current position of the cat as a candidate position for movement. SPC cannot affect the value of SMP

$$X_{cn} = (1 \pm \text{SRD} \times R) \times X_c$$

in which

X_c current position;

X_{cn} new position; and

R a random number, which varies between 0 and 1.

$$P_i = \frac{|FS_i - FS_b|}{|FS_{\max} - FS_{\min}|}, \quad \text{where } 0 < \text{i} < \text{j}$$

where

P_i probability of current candidate cati;

FS_i fitness value of the cati;

FS_{max} maximum value of fitness function;

FS_{min} minimum value of fitness function; and

$FS_b = FS_{max}$ for minimization problems and

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

$FS_b = FS_{min}$ for maximization problems.

5.Tracing Mode (Movement)

The tracing mode simulates the cat chasing a prey. After finding a prey while resting (seeking mode), the cat decides its movement speed and direction based on the prey's position and speed. In CSO, the velocity of cat k in dimension d is given by

$$v_{k,d} = v_{k,d} + r_1 \times c_1 (X_{\text{best},d} - X_{k,d})$$

$$X_{k,d,\text{new}} = X_{k,d,\text{old}} + v_{k,d}$$

in which

$X_{k,d,new}$ new position of cat k in dimension d; and

$X_{k,d,old}$ current position of cat k in dimension d.

6.SIMULINK RESULTS

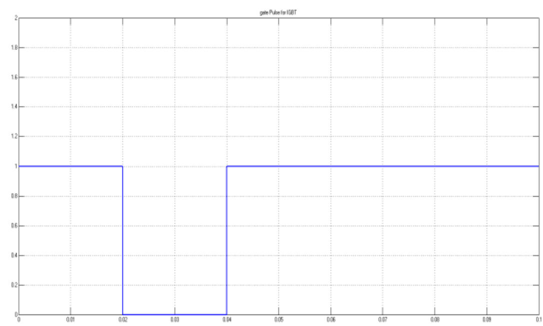


Figure 5.8 generated gate Pulse for IGBT

The Gate pulse generated for the IGBTs in the BSFC-NSFCL is shown in the following figure. The Plot represents that the L-G fault is injected between the time intervals 0.002 to 0.004s. T.The injected 3L-L fault current and voltage are measured with the help V-I measurement block and the corresponding waveforms are shown in the following figure 4.6

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

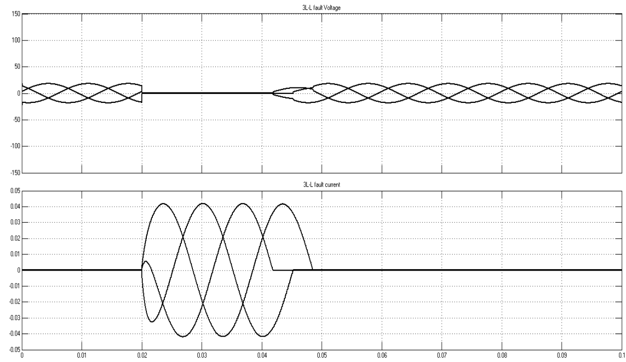


Figure 5.9 3L-L fault voltage and current

The fault current limitation is analyzed on both load side and source side and with and without BSFC-NSFCL block. The current waveforms in the source side with fault on two cases are with and without BSFC-NSFCL is represents in the following figures 4.7 and 4.8 respectively.

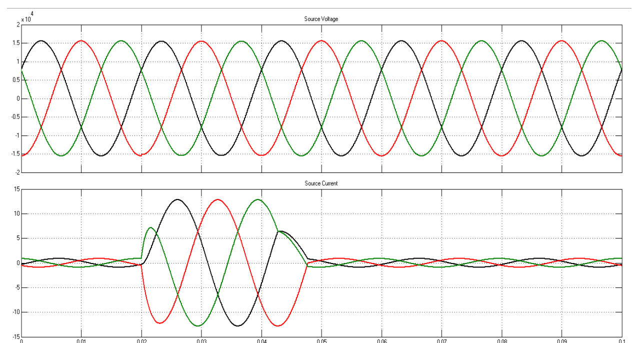


Figure 5.10 Source side current with Fault & without BSFC-NSFCL

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

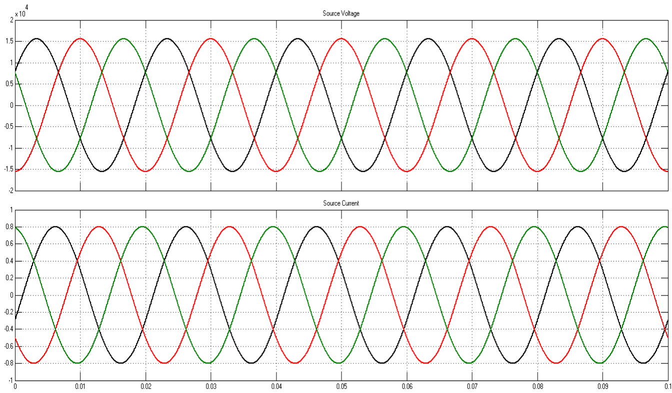


Figure 5.11 Source side voltage & current with Fault &BSFC-NSFCL block

The above waveforms demonstrates the importance of BSFC-NSFCL on the power system very clearly. The source current and voltage are still stable during the fault occurrence time period [0.002 to 0.004s]. By this way the BSFC-NSFCL supports the source side stability at critical scenarios.

The voltage and current waveforms on the load side with fault on two cases ie.with and without BSFC-NSFCL is represents in the following figures 4.9 and 4.10 respectively.

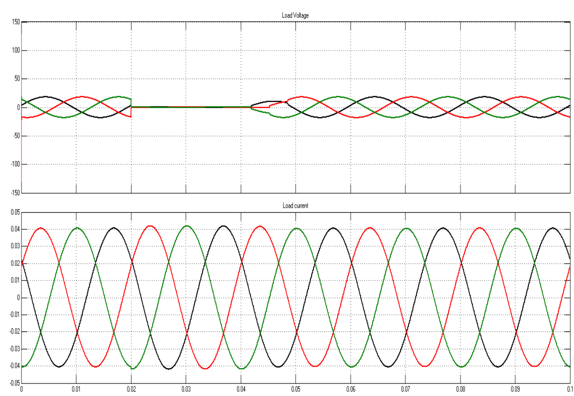


Figure 5.13 Load voltage & current with Fault &BSFC-NSFCL block

The above waveforms demonstrates the importance of BSFC-NSFCL on the power system very clearly. The source current and voltage are still stable during the fault occurrence time period [0.002 to 0.004s]. By this way the BSFC-NSFCL supports the source side stability at critical scenarios.

7. CONCLUSION

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

In this work, a flux-coupling reactor and a bidirectional bridge switch are combined to perform the functions of steady-state line current sharing and fault current suppression. The proposed system is addressing a new and modern optimization tool such as cat swarm optimization (CSO) algorithm. It is generated by observing the behaviors of cats, and composed of two sub-models, i.e., tracing mode and seeking mode, which model upon the behaviors of cats. The modified CSO based BSFC-NSFCL mainly utilizes the magnetic flux cancellation effect to make the limiter behave as a short circuit on the circuit during normal operation. Hence, there is almost no impact on the power system when the limiter is used.

8.REFERENCES

1. Abapou .M and Hagh M.T, “Nonsuperconducting fault current limiter with controlling the magnitudes of fault currents,” IEEE Trans. Power Electron., vol. 24, no. 3, pp. 613–619, Mar. 2009.

2. Jafar. M, Naderi S.B, TarafdarHag.M, Abapour.M, and Hossein S.H “Voltage sag compensation of point of common coupling (PCC) using fault current Limiter,” IEEE Trans. Power Del., vol. 26, no. 4, pp. 2638–2646, Oct. 2011.

3. Kalsi.S, Applications of High Temperature Superconductors to Electric Power Equipment, New York: Wiley-IEEE Press, 2011, pp. 173–217.

4. Nazari-Heris.M, Nourmohamadi.H, Abapour .M and Sabahi .M “Multilevel nonsuperconducting fault current limiter: analysis and practical feasibility,” IEEE Trans. Power Electorn., vol. 32, no. 8, pp. 6059–6068, Aug. 2017.

5. Quaia.S and Tosato.F, “Reducing voltage sags through fault current limitation,” IEEE Trans. Power Del., vol. 16, no. 1, pp. 12–17, Jan. 2001.

6. Radmanesh,.H Fathi, S,H and GharehpetianG.B, “Bridge-type solid-state fault current limiter based on AC/DC reactor,” IEEE Trans. Power Del., vol. 31, no. 1, pp. 200–209, Feb. 2016.