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# Conceptual Design and Performance Evaluation of a 35 kV / 500 A Flux-Coupling-Type SFCL for Protection of a DFIG-Based Wind Farm

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***Abstract***—In this paper, a flux-coupling-type superconducting fault current limiter (SFCL) is suggested to protect a 15 MW class doubly-fed induction generator (DFIG)-based wind farm. Detailed conceptual design and performance evaluation of the SFCL are conducted. By use of different simulation tools, the electrical and electromagnetic characteristics of the SFCL are evaluated. The results show that the maximum magnetic field of the CT is 2.4 T, and the AC loss of the SC is 0.51 W. Not only the electromagnetic properties of the SFCL are well satisfied, but also applying the SFCL in the wind farm enables to suppress the fault current, compensate the voltage sag and mitigate the wind power fluctuation. Thus, the robustness of the DFIG-based wind farm against the fault is enhanced, and the effectiveness of the proposed SFCL design can be well verified.


## 1. The SFCL's structure and application

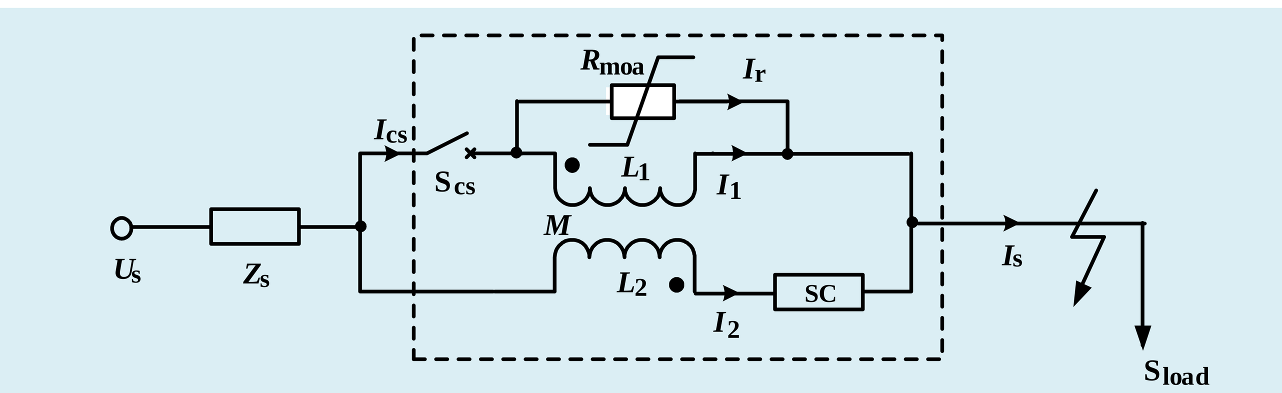



Fig. 1. Configuration structure of the flux-coupling-type SFCL.

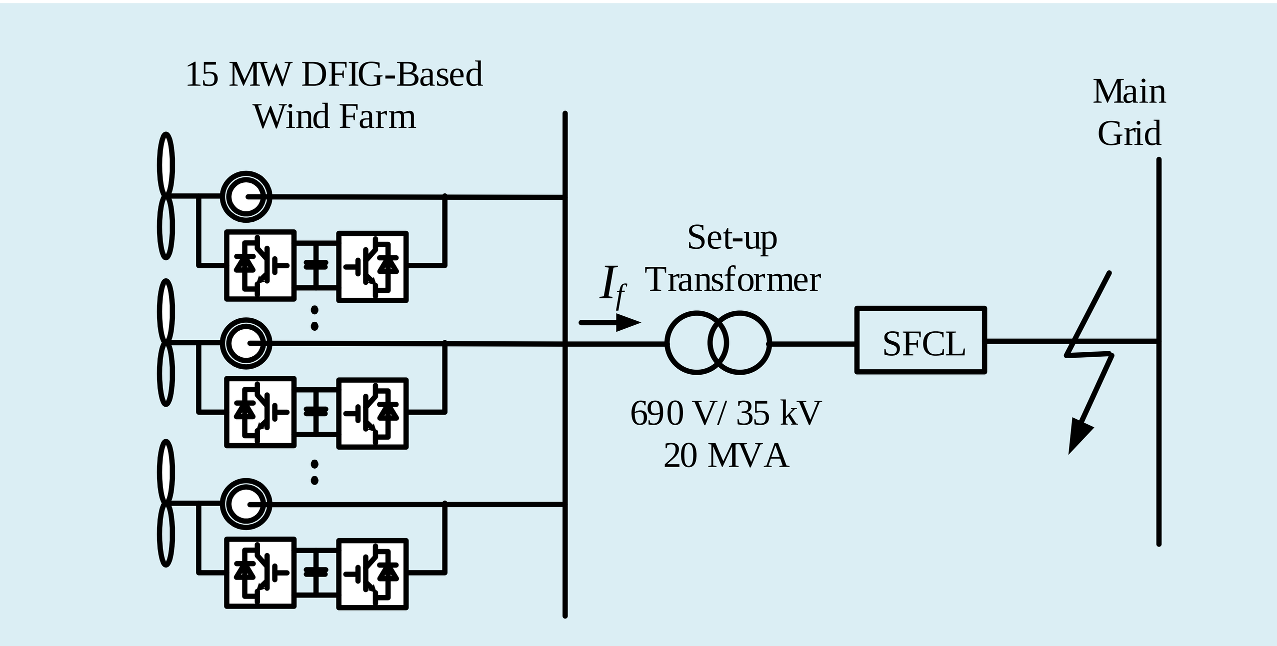



Fig. 2. Schematic diagram of a DFIG-based wind farm with the SFCL.

## 2. Conceptual design of the SFCL

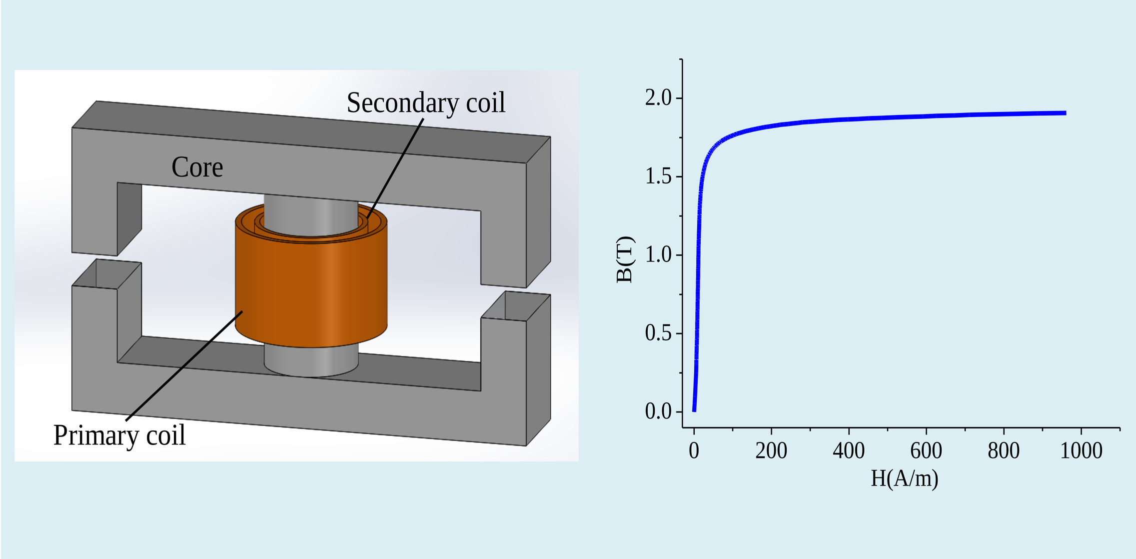



Fig. 3. Layout structure and iron-core properties of the coupling transformer used in the SFCL.

| Core | Inner Diameter<br>Height of window | 310 mm<br>554.5 mm |
|---|---|---|
| Primary winding | Height<br>Turns<br>Layers<br>Current density | 527.5 mm<br>37<br>6<br>1.515 A/mm² |
| Secondary winding | Height<br>Turns<br>Layers<br>Current density | 531 mm<br>53<br>5<br>1.508 A/mm² |

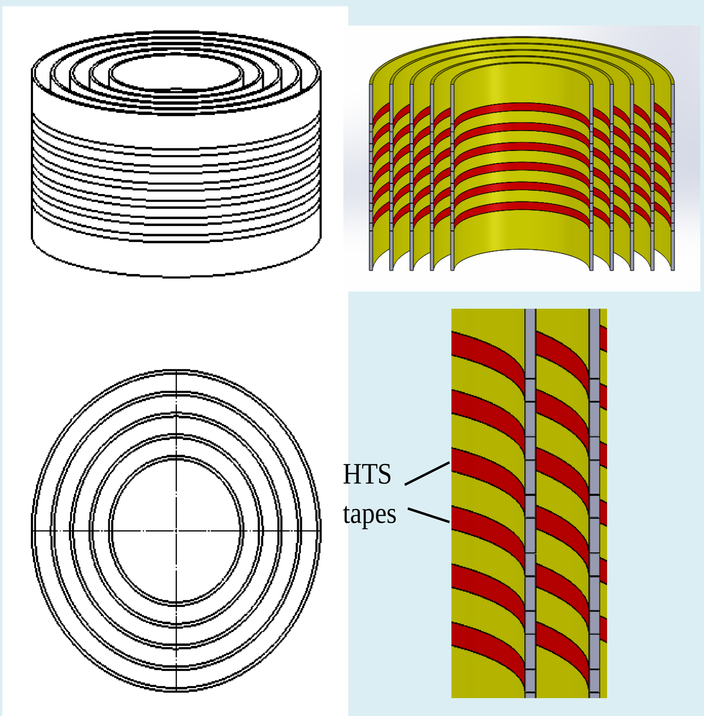



Fig. 4. Schematic design of the superconducting coil used in the SFCL.

| HTS tape parameters | | SC operation parameters | |
|---|---|---|---|
| Tape type | AMSC tape | Working voltage | 35 kV |
| Critical current | 250 A at 77 K, self-field | Maximal operating current | 500 A |
| Tape width | 12 mm | Long-term operating current | 120 A |
| Tape thickness | 0.2 mm | Critical current | 250 A at 77 K, self-field |
| Normal resistance | 110 mΩ/m at 300 K | Number of coil units in series | 4 |
| Tape length | 627 m | SC resistance | 30 Ω |

## 3. Performance evaluation of the designed SFCL in the wind farm

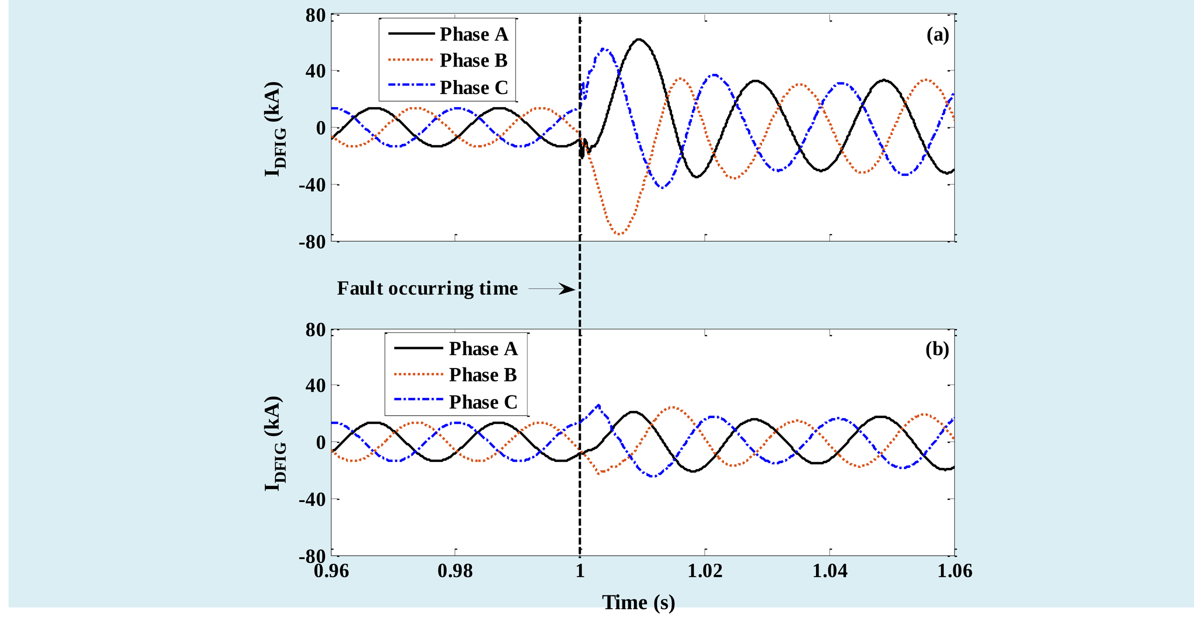



Fig. 5. Fault currents of the wind farm. (a) Without SFCL. (b) With the SFCL.

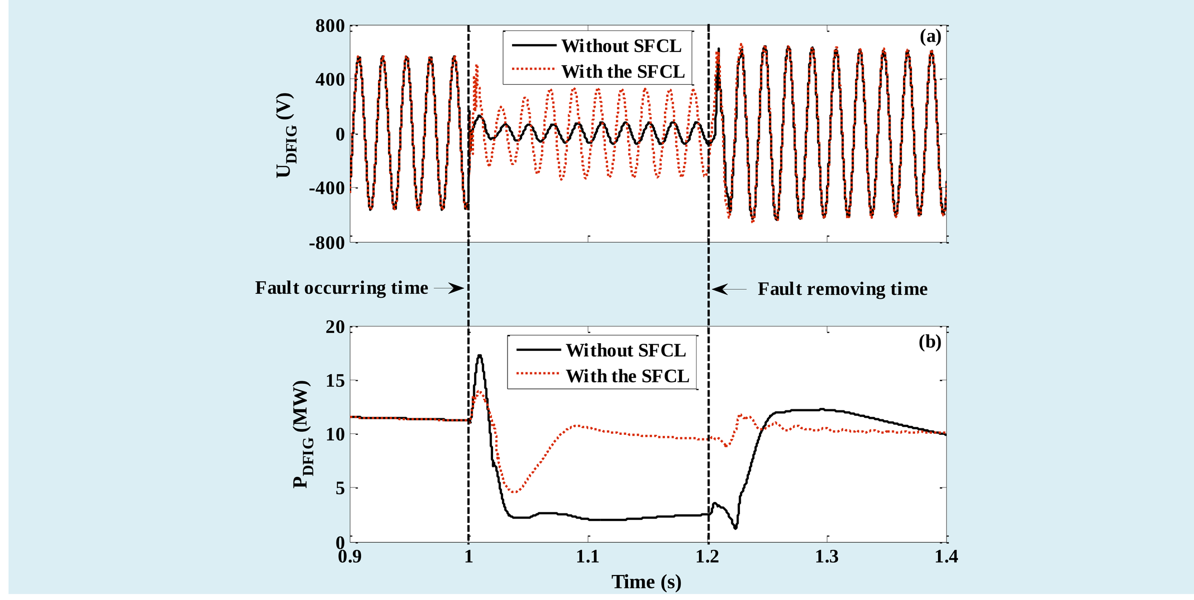



Fig. 6. Effects of the SFCL on the transient behaviors of the DFIG-based wind farm. (a) DFIG terminal-voltage. (b) Active power.

| Flux-Coupling-Type SFCL | |
|---|---|
| Primary/secondary/mutual inductance | 30 mH / 60 mH / 42 mH |
| Superconducting coil $R_{sc}$ | 30 Ω |
| **Power Transformer** | |
| Rated capacity/frequency | 20 MVA / 50 Hz |
| Transformation ratio | 690 V / 35 kV |
| **DFIG-Based Wind Farm** | |
| Rated capacity/voltage | 15 MW / 690 V |
| Number of wind turbine | 10 |

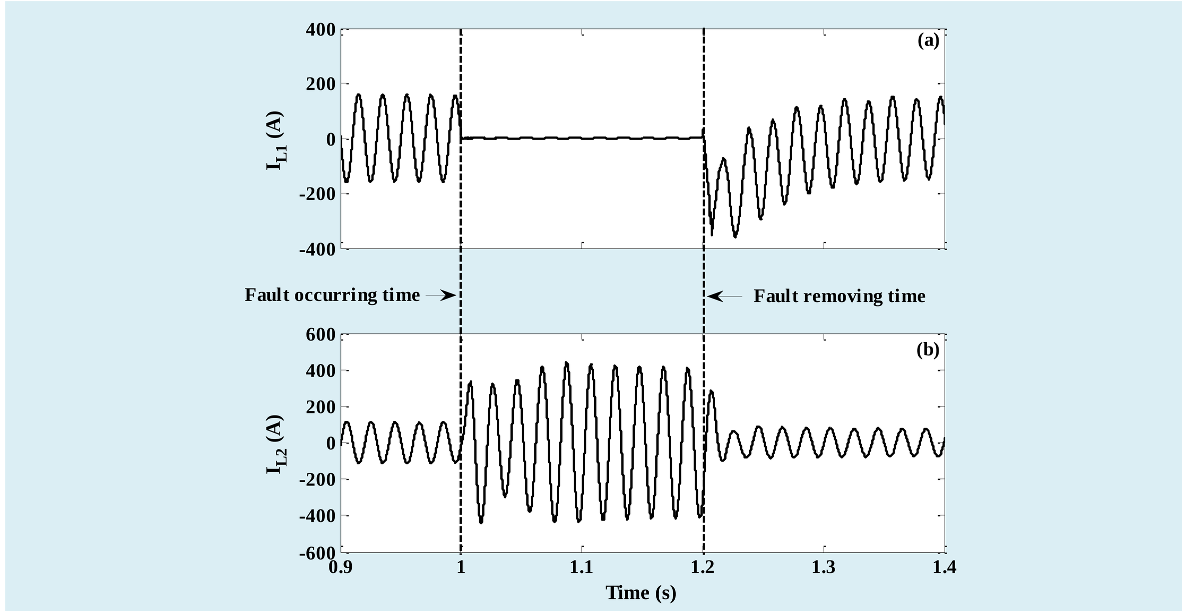
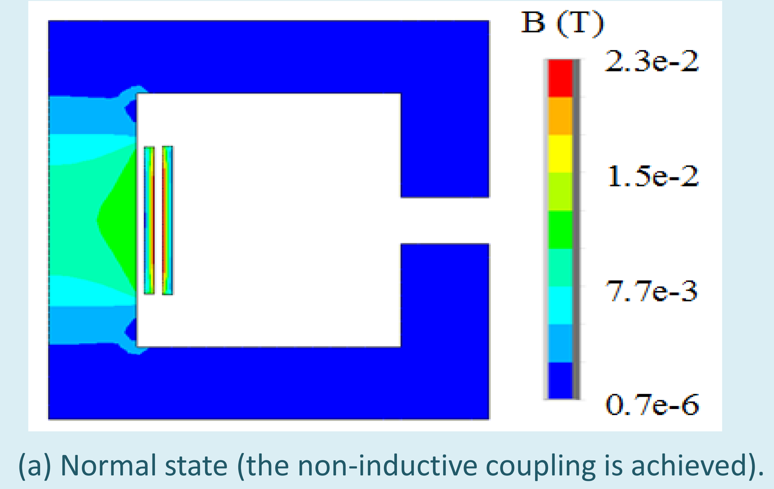


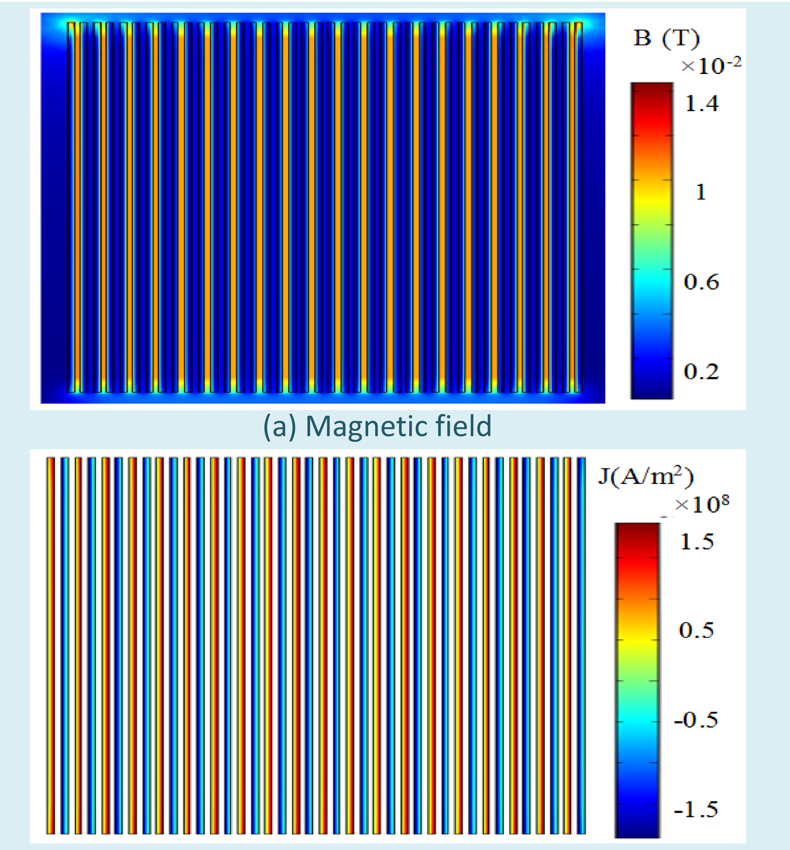

Fig. 7. Change of the currents flowing in the coupling transformer. (a) Primary current. (b) Secondary current.




(a) Normal state (the non-inductive coupling is achieved).

(b) Fault state (the fault current achieves its peak value).

Fig. 8. Magnetic field of the coupling transformer under different conditions.



(a) Magnetic field

(b) Current density

Fig. 9. Operational characteristics of the superconducting coil.

## 4. Conclusion

This paper conducts the conceptual design, electromagnetic analysis and performance evaluation of the 35 kV / 500 A SFCL in a 15 MW class DFIG-based wind farm. Based on the demonstrated simulation results, the effectiveness of the proposed SFCL design is verified. The SFCL's electromagnetic properties can fully meet the requirements, and using the SFCL can effectively limit the fault current, compensate the voltage sag and suppress the wind power fluctuation. Consequently, using the SFCL is able to well enhance the robustness of the DFIG-based wind farm against the short-circuit fault.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