RESEARCH ARTICLE OPEN ACCESS

Improvement of Fault Ride-through capability in DFIG wind turbine with Fuzzy controlled SFCL

T. Kumar raja[1], T. Deepthi Prasanna [2]
1(PG Scholar, EEE Department, Sir C.R.R College of Engineering, Eluru)
2 (Assistant professor, EEE Department, Sir C.R.R College of Engineering, Eluru)

Abstract:

In power systems for smart grid, integration of renewable energy sources and super conducting devices brings more positive effects. This paper suggests a Fuzzy controlled Active Super conducting Fault current limiter (SFCL) to improve the Fault ride-through capability improvement of doubly fed induction generator (DFIG) for wind power generation. Since Fuzzy controlled Active SFCL has higher controllability and flexibility, its application may give better results. Related theory derivation, cost evaluation and simulation are conducted and comparison is performed between with and without Active SFCL. From the results active SFCL can limit the faulty currents flowing through the DFIG's stator and rotor windings and compensate the terminal voltage.

Keywords: **Doubly Fed Induction Generator (DFIG), Super Conducting Fault current Limiter (SFCL).**

I. INTRODUCTION

Concerning the smart grid's technical framework, RE sources and superconducting power devices are two types of crucial components.RE sources that have vast potential to reduce dependence on fossil fuels and their high penetrations into power distribution systems have attracted increasing attention around the world. Superconducting power devices can help to enhance an electric system's operating performance from several aspects, such as limiting current and improvement of transient stability as well as power quality. Therefore an integrated application of RE generation and superconducting power may bring more promising effects.

II. STRUCTURE OF ACTIVE SFCL

Figure 1 shows the topological structure of the Active SFCL, which is composed of three air-core superconducting transformers and a three-phase four-wire converter. L_{s1} and L_{s2} are the winding self inductances, and M_{st} is the mutual inductance. Z_1 is the circuit impedance, and Z_2 is the load impedance. C_{dc1} and C_{dc2} are the split dc-link capacitors. L_f and C_f are used to filter the high-order harmonics caused by the converter. In normal (no fault) state, the injected current in the secondary winding of each phase superconducting transformer will be controlled to keep a certain value, where the magnetic field in the air-core can be compensated to zero, so that the active SFCL will not affect the main circuit. When a short circuit fault is detected, the injected current corresponding to the faulted phase will be timely adjusted in amplitude or phase angle, so as to control the series compensation voltage and suppress the fault current.

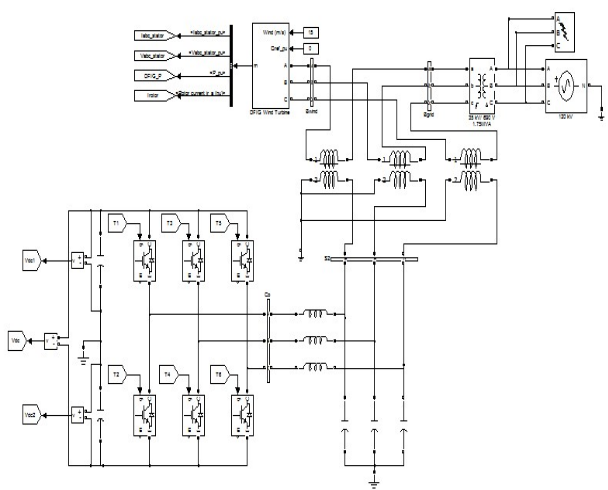


Fig. 1 Basic simulink model of Active SFCL

The equations for Current and Voltage in the primary and secondary windings of super conducting transformers are as follows

$$\underline{\dot{V}}_{gA} = \dot{I}_{s1A}(Z_1 + Z_2) + j\omega L_{s1}\dot{I}_{s1A} - j\omega M_{st}\dot{I}_{s2A} \quad (1)$$

$$\dot{I}_{s2A} = \frac{\dot{I}_{s1A}L_{s1}}{M_{st}} = \frac{\dot{I}_{s1A}\sqrt{L_{s1}/L_{s2}}}{k} = \frac{\dot{V}_{gA}\sqrt{L_{s1}/L_{s2}}}{(Z_1+Z_2)k} \quad (2)$$

$$\dot{V}_{s1A-F} = j\omega L_{s1}\dot{I}_{s1A-F} - j\omega \quad {}_{st}\dot{I}_{s2A} \quad (3)$$

$$\dot{I}_{s1A-f} = \frac{\dot{V}gA + j\omega M_{st}\ddot{I}_{s2A}}{Z_1 + j\omega L_{s1}} \quad (4)$$

III. CONTROL STRATEGY

To make the active SFCL have higher controllability and flexibility, this section suggests a suitable control strategy for the converter. Assuming that the switching devices are ideal and C_{dc1}=C_{dc2}, the following mathematical equations can be derived (R denotes the equivalent resistance of L_f).

$$L_f\frac{di_{coA}}{dt} + Ri_{coA} = -v_{s2A} + v_{coA} \quad (5)$$

$$L_f\frac{di_{coB}}{dt} + Ri_{coB} = -v_{s2B} + v_{coB} \quad (6)$$

$$L_f\frac{di_{coC}}{dt} + Ri_{coC} = -v_{s2C} + v_{coC} \quad (7)$$

$$C_f\frac{dv_{s2d}}{dt} = \omega C_f v_{s2q} + i_{cod} - i_{s2d} \quad (8)$$

$$C_f\frac{dv_{s2q}}{dt} = -\omega C_f v_{s2d} + i_{coq} - i_{s2q} \quad (9)$$

$$C_f\frac{dv_{s20}}{dt} = i_{co0} - i_{s20} \quad (10)$$

Furthermore, the mathematical equations in dq0 reference frame can be obtained

$$L_f\frac{di_{cod}}{dt} = -Ri_{cod} + \omega L_f i_{coq} - u_{s2d} + u_{cod} \quad (11)$$

$$L_f\frac{di_{coq}}{dt} = -Ri_{coq} - \omega L_f i_{cod} - u_{s2q} + u_{coq} \quad (12)$$

$$L_f\frac{di_{co0}}{dt} = -Ri_{co} - u_{s20} + u_{co0} \quad (13)$$

$$C_f\frac{dv_{s2A}}{dt} = i_{coA} - i_{s2A} \quad (14)$$

$$C_f\frac{dv_{s2B}}{dt} = i_{coB} - i_{s2B} \quad (15)$$

$$C_f\frac{dv_{s2C}}{dt} = i_{coC} - i_{s2C} \quad (16)$$

After dq0 transformation, the control objects (vs2dandvs2q) can be determined, and the control system designed for the three-phase four-wire converter should be consisting of two subsystems:

1) Coupling dq-axis system that needs to be decoupled and

2) 0-axis system. Since the injected currents (I_{s2A}, I_{s2B},and I_{s2C}) will be unbalanced under unsymmetrical fault conditions, not only the sum of V_{dc1} and V_{dc2} should be essentially controlled to maintain a constant value, but also the voltage balance control for the split dc-link capacitors (C_{dc1} and C_{dc2})should be considered.

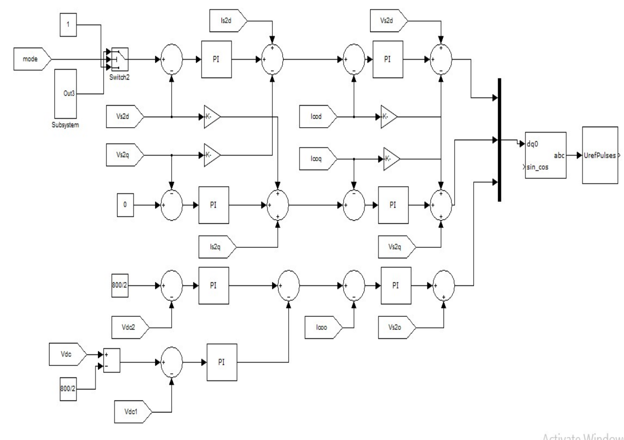


Fig. 2 Control circuit for Active SFCL

IV. SIMUATION STUDY OF WITH FUZZY CONTROLLED SFCL

Figure 3 shows the simulation circuit of DFIG based wind turbine by employing Fuzzy controlled type Active SFCL. Since power system dynamic characteristics are complex and variable, conventional control methods cannot provide desired results. Intelligent controllers can be replaced with conventional controllers to get fast and good dynamic response in load frequency control problem. If the system robustness and reliability are more important, fuzzy logic controllers can be more useful in solving a wide range of control problems since conventional controllers are slower and also less efficient in nonlinear system applications. Fuzzy logic controller is designed to minimize fluctuation on system outputs. FLC designed to eliminate the need for continuous operator attention and used automatically to adjust some variables the process variable is kept at the reference value.

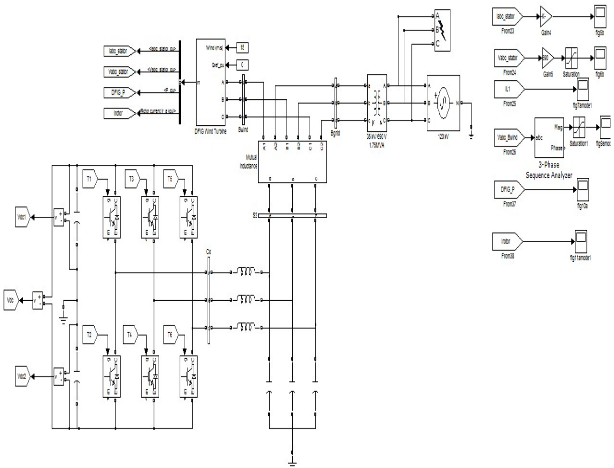


Fig. 3 Simulink Model of DFIG with Active SFCL

Figure 4 shows the Fuzzy logic controller used in the Active SFCL.

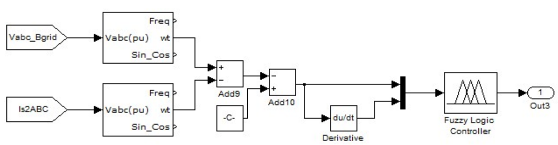


Fig. 4 Fuzzy logic controller used in Active SFCL

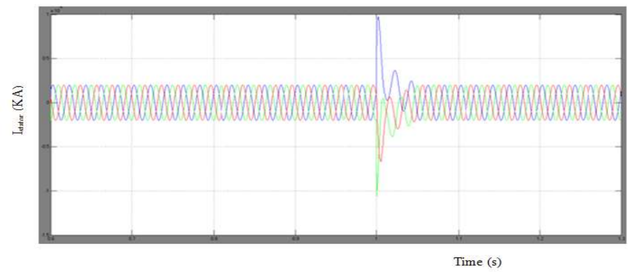
Figure 5 shows the rule base used for Active SFCL

Change in error	Error						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PB	PM	PS	PS	Z	NM	NB
Z	PB	PM	PS	Z	NS	NM	NB
PS	PM	PS	Z	NS	NM	NB	NB
PM	PS	Z	NS	NM	NM	NB	NB
PB	Z	NS	NM	NM	NB	NB	NB

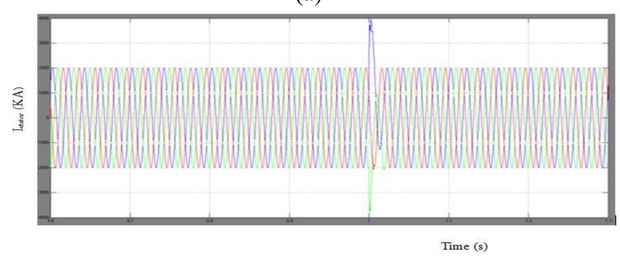
Fig. 4 rule base for Active SFCL

V. RESULTS

In normal condition, the line current's peak value is 1.75 kA. Supposing that a three-phase grounded fault happens at t = 1 s, and the fault duration/resistance is 0.4 s/0.1 Figures show the operational characteristics of the DFIG-based wind turbine without and with the active SFCL (only mode 1 plays its role). Figures 5 (a) and (b) shows the DFIG based Wind turbine stator current wave forms with and without Active SFCL



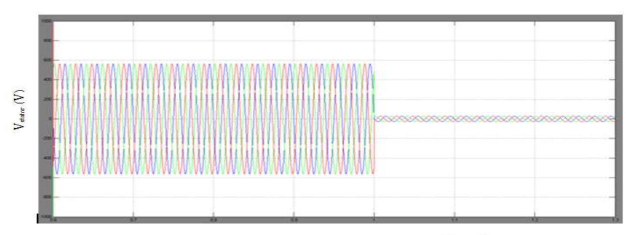
(a)



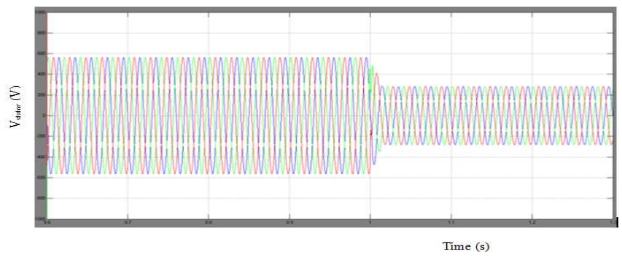
(b)

Fig. 5 Stator current waveform of DFIG (a) Without Active SFCL
(b) With Active SFCL

It is observed that employing the active SFCL can also compensate the DFIG's terminal voltage to 60% of normal value. By contrast, the terminal voltage will decrease to 7% of normal value without any additional current-limiting or voltage-compensation devices. Figures 6 (a) and (b) will show the Stator voltage waveform of DFIG based Wind turbine with and without Active SFCL.



(a)



(b)

Fig. 6 Stator voltage waveform of DFIG (a) Without Active SFCL (b) With Active SFCL

Concerning the DFIG's power fluctuation and rotor fault current under the unsymmetrical fault, the active SFCL's effects on them are indicated in Figures .From this figures 7 and 8, applying the active SFCL can availably reduce the DFIG's power fluctuation, and the inhibition rate is 32.1%. Meanwhile, the increase of the circuit impedance will slightly lengthen the duration of the fluctuation process.

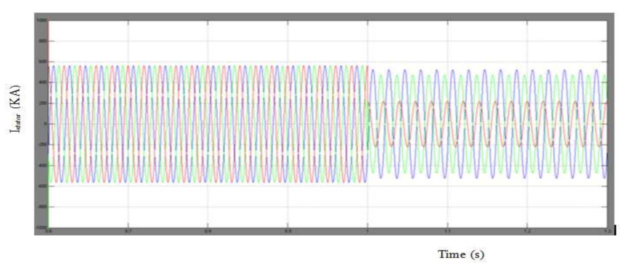
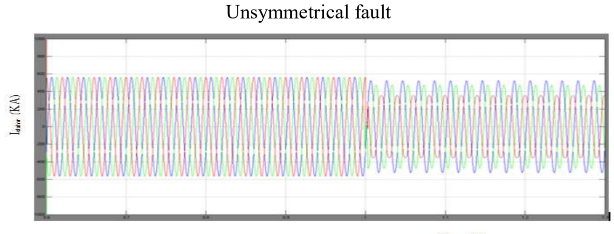


Fig. 7 Output waveform of DFIG Power fluctuation under Unsymmetrical fault



(b)

Fig. 8 Output waveform of DFIG Rotor current under Unsymmetrical fault

VI. CONCLUSION

In this paper, according to theory derivation and simulation analysis the application of a Fuzzy controlled type active SFCL improves the FRT capability of DFIG-based wind turbine. From the results, the following conclusions can be obtained. 1) Installing the active SFCL can effectively limit the fault currents flowing through the DFIG's stator and rotor windings. 2) Applying the active SFCL can evidently compensate the DFIG's terminal-voltage and decrease its output power fluctuation, which helps to strengthen the operational stability of the wind power integrated system.

VII. REFERENCES

[1] V. C. Gungor., "Smart grid technologies: Communication technologies and standards," IEEE Trans. Ind. Information vol. 7, no. 4, pp. 529–539, Nov. 2011.

[2] G. W. Arnold, "Challenges and opportunities in smart grid: A position article," Proc. IEEE, vol. 99, no. 6, pp. 922–927, Jun. 2011.

[3] A. A. Moghaddam and A. R. Seifi, "Study of forecasting renewable energies in smart grids using linear predictive filters and neural networks," IET. Renewable Power Generation vol. 5, no. 6, pp. 470–480, Nov. 2011.

[4] M. Hamzeh, H. Mokhtari, and H. Karimi, "A decentralized self-adjusting control strategy for reactive power management in an islanded multi-bus MV microgrid," Can. J. Elect. Computer Engineering vol. 36, no. 1, pp. 18–25, Winter 2013.

[5] I. N.gamroo and S. Vachirasricirikul, "Coordinated control of optimized SFCL and SMES for improvement of power system transient stability," IEEE Trans. Applied Superconductors, vol. 22, no. 3, Jun. 2012, Art. ID 5600805.

[6] A. Morandi, "Fault current limiter: An enabler for increasing safety and power quality of distribution networks," IEEE Trans. Applied Superconductors, vol. 23, no. 6, Dec. 2013, Art. ID 5604608.

[7] Y. Xin, "Factory and field tests of a 220 kV/300 MVA statured iron-core superconducting fault current limiter," IEEE Trans. Applied Superconductors, vol. 23, no. 3, Jun. 2013, Art. ID 5602305.

[8] J.W.Shim, Y.Cho, S.J.Kim, S.W.Min, and K.Hur, "Synergistic control of SMES and battery energy storage for enabling dispatchability of renewable energy sources," IEEE Trans. Applied Superconductors, vol. 23, no. 3, Jun. 2013, Art. ID 5701205.

[9] R. Qu, Y. Liu, and J. Wang, "Review of superconducting generator topologies for direct-drive wind turbines," IEEE Trans. Applied

Superconductors, vol. 23, no. 3, Jun. 2013, Art. ID 5201108.
[10] N. G. A. Hemdan and M. Kurrat, "Time series analysis of rural distribution grids in the presence of HTS cables and intermittent renewable resources," IEEE Trans. Applied Superconductors, vol. 24, no. 5, Oct. 2014, Art. ID 5400507.