ENHANCEMENT OF OPEN CIRCUIT FAULT IN OUTER SWITCHES OF THREE LEVEL RECTIFIERS IN WIND TURBINE SYSTEMS USING FAULT TOLERANT CONTROL METHOD

M.SHIRISHA[1]

[1]**PG Scholar, Dept. Of E.E.E., JNTUA, Anantapur, A.P.**

Abstract:

In the wind generation system, the variable-speed generation system is more attractive than the fixed-speed system because of the improvement in wind energy production and the reduction of the flicker problem by the variable-speed generation. The proposed method can not only detect the fault condition but also identify the location of the faulty switch. In the proposed method, this is designed by incorporating a simple switching control in the conventional method. By using the closed-loop control systems, an analysis of the system discloses that it is possible for signal energy to traverse different paths and to be modified in a different manner in these various paths without using additional sensors or performing complex calculations. The reasons for using multiple-loop systems are many that is Improved linearization, noise reduction, and change in impedance level can be achieved by using auxiliary loops. It is also possible to synthesize certain transfer functions by using additional feed-back paths. For the fault detection of the NPC-type rectifier, the fault detection method which uses a dc-link voltage with a grid angle is proposed. The proposed tolerant Control maintains normal operation with sinusoidal currents under the open-circuit fault of outer switches by adding a compensation value to the reference voltages. Three-level topologies are widely used in back-to-back converters of wind turbine generation systems. Simulations and experiments are carried out to confirm the reliability of the proposed fault-detection method.

Index Terms— Neutral-point-clamped rectifier, open-circuit fault, open-switch fault, reliability, three-level topology, tolerant control, T-type rectifier.

I.INTRODUCTION:

Multilevel inverters are becoming increasingly popular because of their advantages over conventional two level converters. For example, their output ac voltage provides lower *dv/dt* values and reduced total harmonic distortion (THD).

In addition, semiconductor devices are operated at low voltage stress. A neutral-point clamped inverter, often known as an NPC inverter, is the most widely used multilevel inverter. In order to generate different voltage levels, the T-type and NPC inverters comprise two dc-link capacitors connected in series. However, this topology can lead to an unbalanced neutral point voltage, which causes increased voltage stress on the switching device. It also increases the THD of the output current because a low-order harmonic will appear in the output voltage. To maximize the performance of the three-level inverter system and to achieve a balanced neutral-point voltage, the voltages of series connected dc-link capacitors should be equal. For the input side of the rectifier, this current distortion increases total harmonic distortion (THD) and adversely affects the grid. Moreover, the power factor of the rectifier decreases, and the dc-link ripple increases. If the open switch fault is not detected for a long time, other problems are generated because the distorted current is used to control this rectifier. Consequently, the open-switch fault should be detected quickly, and the tolerance control should be applied if these are possible.

II IPMSG:

IPM are commonly used for variable-speed wind turbines to produce high efficiency, high reliability, and low-cost wind power generation. The effect of magnetic saturation, which causes the highly nonlinear characteristics of the IPMSG, has been considered in the control scheme design. The optimal d-axis stator-current command is obtained as a function of the IPMSG rotor speed by solving a constrained nonlinear optimization problem that minimizes the copper and core losses of the IPMSG. At any wind speed within the operating range, the IPMSG rotor speed is optimally controlled to extract maximum wind power. The IPMSG converts the mechanical power from the wind turbine to ac electrical power, which is then converted to dc power through an IGBT pulse-width modulation (PWM) converter with a dc link to supply the dc load. Control of the IPMSG is achieved by controlling the ac-side voltages of this PWM power converter. By using an additional power inverter, the IPMSG can supply the ac electrical power with constant voltage and frequency to the power grid or ac load.

III OPEN LOOP METHOD:

The existing method using switch faults in power converters connecting doubly-fed induction generator wind turbine systems to the grid. The detection method combines a simple Fault Tolerant

Control (FTC) strategy with fuzzy logic and uses rotor current average values to detect the faulty switch in a very short period of time. In addition, following a power switch failure, the FTC strategy activates the redundant leg and restores the operation of the converter.

Faulty switches produce unbalanced AC input currents including harmonics and distortions, which may result in severe secondary faults in the other devices . In this work, a fault detection and isolation method of inverter open switch faults is proposed which can be equally applied to the rectifier circuit.

In wind turbine systems, a back-to-back converter is used to transfer power from the generator to the grid. A back-to-back converter using the 3L-NPC topology is shown in Fig.1.

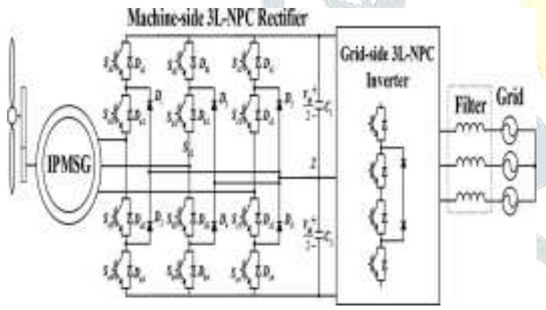


Fig. 1. Back-to-back converter using the 3L-NPC topology in wind turbine systems.

The most frequently used converter configuration with modeling and simulation of PMSG based wind energy conversion is this type, and it is also called as (back to back) voltage source converter. It consist of fully controlled converters with intermediate DC-link as shown in figure.1. Low voltage, high current level, and reliability demands require parallel operation of such converter.

This consists of the machine-side 3L-NPC rectifier, the dc-link, and the grid-side 3L-NPC inverter. Depending on the operating conditions, tolerant controls can be applied for the rectifier or the inverter because the current paths of the rectifier and the inverter are different.

IV. OPEN CIRCUIT FAULT ANALYSIS OF OUTER SWITCHES:

There are three switching states (P, N, and O) in the 3L-NPC rectifier . Six current paths can be generated depending on the current direction and the switching state, and these are shown in Fig. 2 [23].

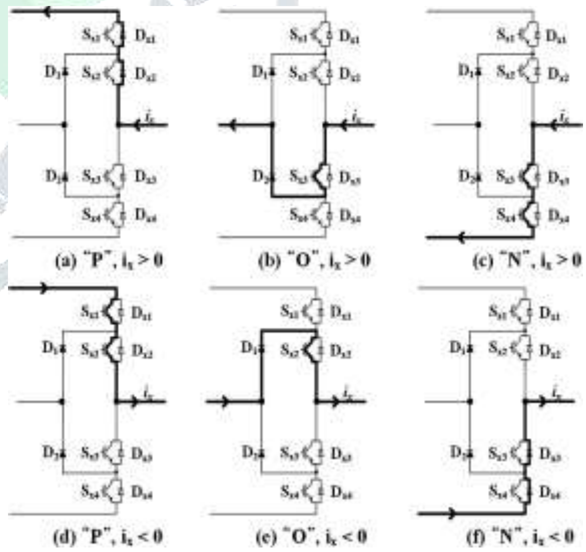


Fig. 2. Current paths depending on the current direction and the switching state.

IPMSGs provide more power when rectifiers operate at a unique *pf* .[4]-[7]. In such a case, an open-circuit fault of the outer switches ($Sx1$ and $Sx4$) causes current distortion and torque fluctuation, which can lead to vibration of the wind turbine. In this project, the reason for the current distortion caused by the outer switches ($Sx1$ and $Sx4$) is analyzed, and then, on the basis of this analysis, a tolerant control for $Sx1$ and $Sx4$ open-circuit faults is proposed. In the proposed tolerant control, the switch with an open-circuit fault is not used to generate the input voltages of the three-level rectifier by adding a compensation value to the reference voltages. The compensation value is simply calculated and the *pf* does not change in the proposed tolerant control.

V. COMPENSATING VOLTAGE CALCULATION:

The compensating voltages V_{ac} ,V_{bc}, V_{cc} which is synthesized by the series Pulse width modulation converter. The input are the control voltages determined by the voltage detector.

V_{a1},V_{b1}, V_{c1} are the voltage detector

V_{as} ,V_{bs} ,V_{cs} are the source voltages

V_{ah} ,V_{bh}, V_{ch} are the damping voltages

The compensating voltages are given by

$$V_{ac} = V_{a1} - (V_{as} + V_{ah}) \quad (1)$$

$$V_{bc} = V_{b1} - (V_{b1} + V_{bh}) \quad (2)$$

$$V_{cc} = V_{c1} - (V_{cs} + V_{ch}) \quad (3)$$

The compensated voltages delivered to the critical load will comprise only the fundamental positive sequence component (V_{a1},V_{b1}, V_{c1}) of the supply voltage V_s, the voltages will improve stability and provide harmonic isolation.

VI. CLOSED LOOP METHOD:

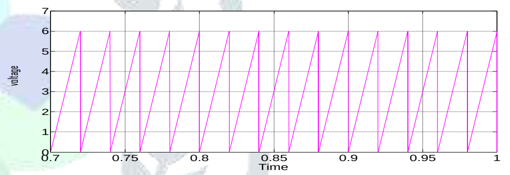
The proposed method of the output has an effect on the input quantity in such a manner that the input quantity will adjust itself based on the output generated. Feedback loop is the tool which take the system output in to the consideration and enables the system to adjust its performance to meet a desired result of system.

VII. SIMULATION RESULTS

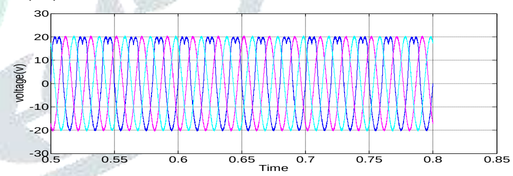
1.OPEN LOOP METHOD

(A) Simulation results for without tolerant control under the *Sa* 1 open-circuit fault (600 rpm, *Ma* = 0.35, 0.95 *pf*).

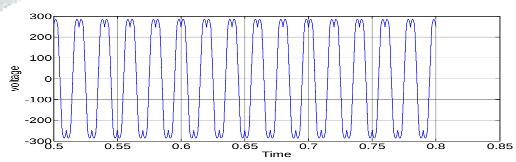
1. θ_{EMF}



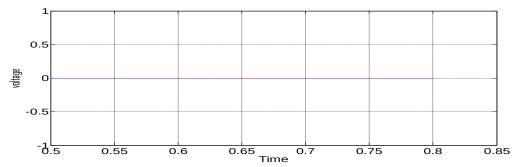
2. I_a,I_b,I_c



3. Va,ref,tolerance

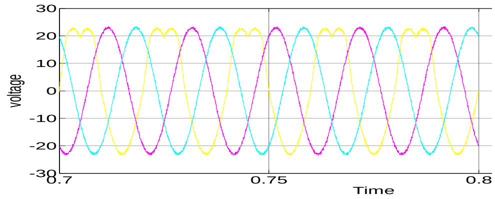


4. Vcomp

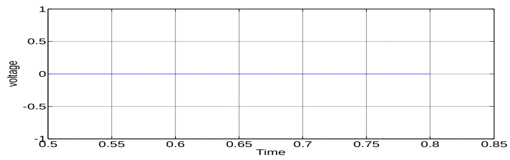


(B) Simulation results for without tolerant control under the *Sa* 1 open-circuit fault (1000 rpm, *Ma* = 0.59, 0.95 *pf*).

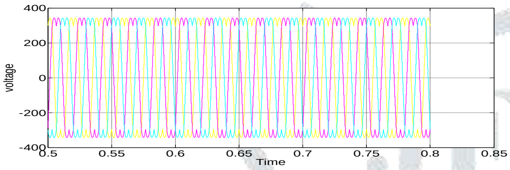
1. I_a, I_b, I_C



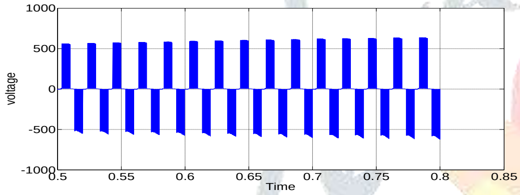
2. Vcomp



3. Va,ref,tolerance

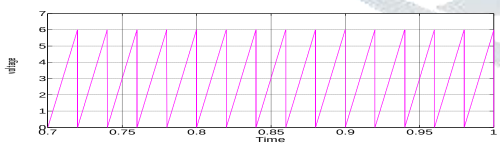


4. V_{an}

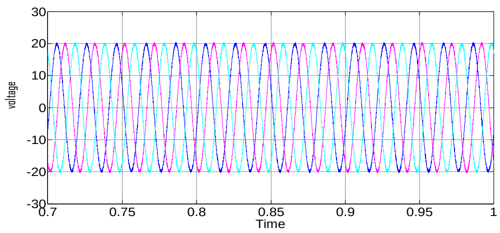


(C) Simulation results for with tolerant control under the *Sa* 1 open-circuit fault (600 rpm, *Ma* = 0.35, 0.95 *pf*).

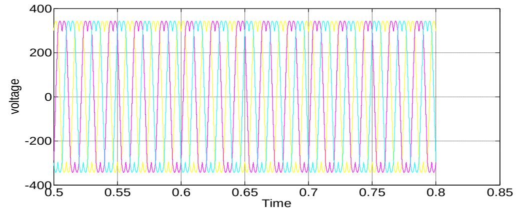
1. θ_{EMF}



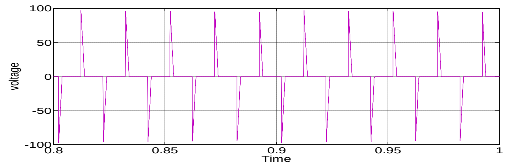
2. I_a, I_b, I_C:



3 . Va,ref,tolerance:

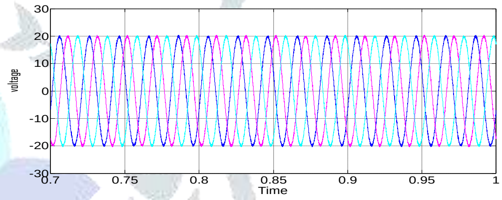


4. V_{comp}

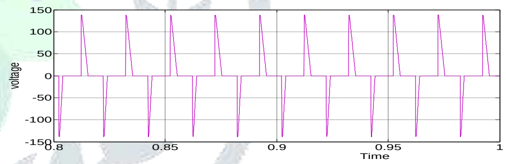


(D) Simulation results for with tolerant control under the *Sa* 1 open-circuit fault (1000 rpm, *Ma* = 0.59, 0.95 *pf*

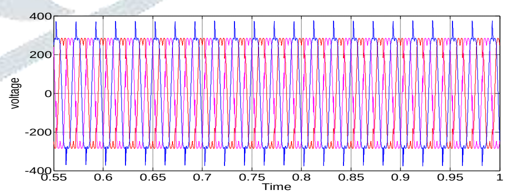
1. I_a, I_b, I_C



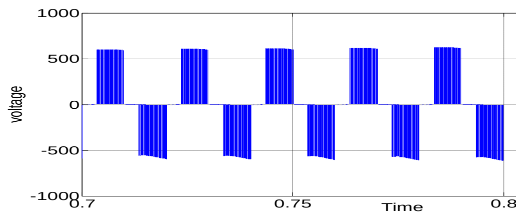
2. V_{comp}



3. Va,ref,tolerance



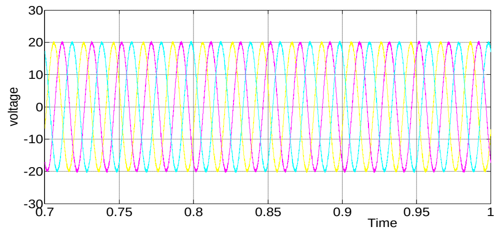
4. V_{an}



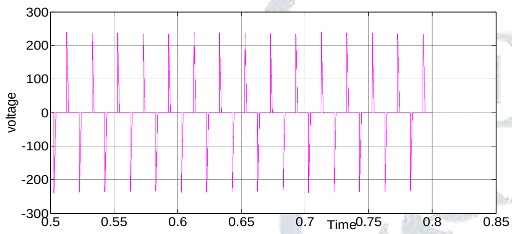
2.CLOSED LOOP METHOD

(A) Without tolerant control

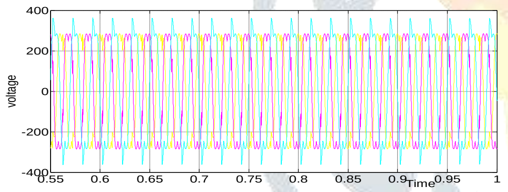
1.I_a, I_b, I_C



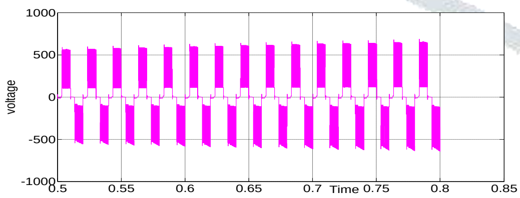
2.V_{Comp}



3. V-Tolerant

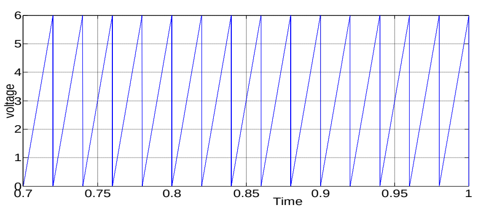


4. Vabcg

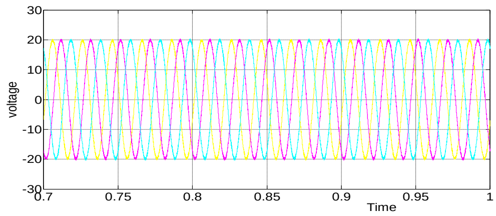


(C) With tolerant control

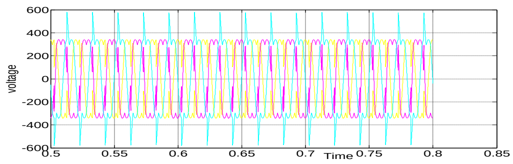
1. Vabcs



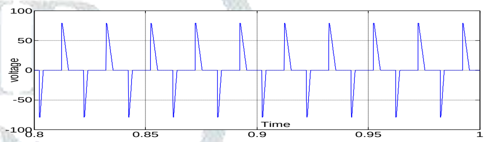
2.Iabcs



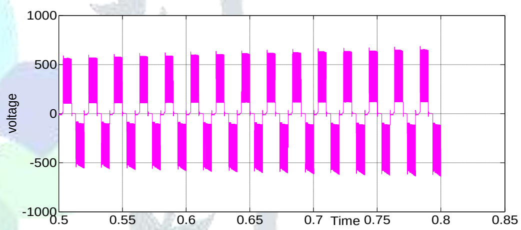
3.v-tolerant



4.V_a



5.V_{abcg}



VIII CONCLUSION:

The closed loop control system offers high efficiency better performance over the open loop control system. The cost function considering the elimination of power ripples and dc-link split voltage balance control is used to select the optimal voltage vector, which achieves flexible smooth switching between inverter and rectifier mode with direct power control. With the proposed scheme, the dc voltage offset component can also be minimized to keep the central point of the dc-link voltage offset suppression. The flexible switching between the inverter and the rectifier mode of the fault-tolerant is bidirectional voltage source converter achieved by changing the reference active power. The proposed system using closed loop control has operated successfully and gives less harmonic distortion than the open loop control which is verified by the simulation results shown.

REFERENCES

[1] A. Isidori, F. M. Rossi, F. Blaabjerg, and K. Ma, "Thermal loading and reliability of 10-MW multilevel wind power converter at different wind roughness classes," *IEEE Trans. Ind. Appl.*, vol. 50, no. 1, pp. 484–494, Jan./Feb. 2014.

[2] H. G. Jeong, K. B. Lee, S. Chio, andW. Choi, "Performance improvement of LCL-filter-SSbased grid-connected inverters using PQR power transformation," *IEEE Trans. Power Electron.*, Svol. 25, no. 5, pp. 1320–1330, May 2010.

[3] S. Li, T. A. Haskew, R. P. Swatloski, and W. Gathings, "Optimal and direct-current vector control of direct-driven PMSG wind turbines," *IEEE Trans. Power Electron.*, vol. 27, no. 5, pp. 2325–2337, May 2012.

[4] W. Qiao, L. Qu, and R. G. Harley, "Control of IPM synchronous generator for maximum wind power generation considering magnetic saturation," *IEEE Trans. Ind. Appl.*, vol. 45, no. 3, pp. 1095–1105, May/Jun. 2009.

[5] S.Morimoto, H. Nakayama,M. Sanada, andY. Takeda, "Sensorless output maximization control for variable-speed wind generation system using IPMSG," *IEEE Trans. Ind. Appl.*, vol. 41, no. 1, pp. 60–67, Jan./Feb. 2005.

[6] Y. Zhao, W. Qiao, and L. Wu, "An adaptive quasi-sliding-mode rotor position observer-based sensorless control for interior permanent magnet synchronous machines," *IEEE Trans. Power Electron.*, vol. 28, no. 12, pp. 5618–5629, Dec. 2013.

[7] P. B. Reddy, A. M. EL-Refaie, and K. K. Huh, "Effect of number of layers on performance of fractional-slot concentrated-windings interior permanent magnet machines," *IEEE Trans. Power Electron.*, vol. 30, no. 4, pp. 2205–2218, Apr. 2015.

[8] J. S. Lee and K. B. Lee, "New modulation techniques for a leakage current reduction and a neutral-point voltage balance in transformerless photovoltaic systems using a three-level inverter," *IEEE Trans. Power*

Electron., vol. 29, no. 4, pp. 1720–1732, Apr. 2014.

[9] U. M. Choi, H. G. Jeong, K. B. Lee, and F. Blaabjerg, "Method for detecting an open-switch fault in a grid-connected NPC inverter system," *IEEE Trans. Power Electron.*, vol. 27, no. 6, pp. 2726–2739, Jun. 2012.

[10] U. M. Choi, J. S. Lee, and K. B. Lee, "New modulation strategy to balance the neutral-point voltage for three-level neutral-clamped inverter systems," *IEEE Trans. Energy Convers.*, vol. 29, no. 1, pp. 91–100, Mar. 2014.

[11] M. Schweizer and J. W. Kolar, "Design and implementation of a highly efficient three-level t-type converter for low-voltage applications," *IEEE Trans. Power Electron.*, vol. 28, no. 2, pp. 899–907, Feb. 2013.

[12] U. M. Choi, F. Blaabjerg, and K. B. Lee, "Reliability improvement of a type three-level inverter with fault-tolerant control strategy," *IEEE Trans. Power Electron.*, vol. 30, no. 5, pp. 2660–2673, May 2015.

[13] J. S. Lee and K. B. Lee, "An open-switch fault detection method and tolerance controls based on SVM in a grid-connected t-type rectifier with unity power factor," *IEEE Trans. Ind. Electron.*, vol. 61, no. 12, pp. 7092–7104, Dec. 2014.

[14] H. K. Ku,W. S. Im, J. M. Kim, and Y. S. Suh, "Fault detection and tolerant control of 3-phase NPC active rectifier," in *Proc. IEEE Energy Convers. Congr. Expo.*, Sep. 2012, pp. 4519–1524.

[15] J. S. Lee, K. B. Lee, and F. Blaabjerg "Open-switch fault detection method of an NPC converter for wind turbine systems," in *Proc. IEEE Energy Convers. Congr. Expo.*, Sep. 2013, pp. 1696–1701.

[16] S. Ceballos, J. Pou, E. Robles, J. Zaragoza, and J. L. Mart´ın, "Performance evaluation of fault-tolerant neutral-point-clamped converters," *IEEE Trans. Ind. Electron.*, vol. 57, no. 8, pp. 2709–2718,Aug. 2010.

[17] J. Li, A. Q. Huang, Z. Liang, "Analysis and design of active NPC (ANPC) inverters for fault-tolerant operation of high-power electrical drives," *IEEE Trans. Power Electron.*, vol. 27, no. 2, pp. 519–533, Feb. 2012

[18] Y. Song and B.Wang, "Survey on reliability of power electronic systems,"*IEEE Trans. Power Electron.*, vol. 28, no. 1, pp. 591–604, Jan. 2013.

[19] S. Li and L. Xu, "Strategies of fault tolerant operation for three-level PWM inverters," *IEEE Trans. Power Electron.*, vol. 21, no. 4, pp. 933–940, Jul. 2006.

[20] J. S. Lee, U. M. Choi, and K. B. Lee, "Comparison of tolerance controls for open-switch fault in a grid-connected T-type rectifier," *IEEE Trans. Power Electron.*, vol. 30, no. 10, pp. 5810–5820, Nov. 2014.

[21] U. M. Choi, F. Blaabjerg, and K. B. Lee, "Reliability improvement of a T type three-level inverter with fault-tolerant control strategy," *IEEE Trans. Power Electron.*, vol. 30, no. 5, pp. 2660–2673, May 2015.

[22] J. S. Lee and K. B. Lee, "Open-switch fault tolerance control for a three level NPC/T-type rectifier in wind turbine systems," *IEEE Trans. Ind. Electron.*, vol. 62, no. 2, pp. 1012–1021, Feb. 2015.

[23] J. S. Lee, K. B. Lee, and F. Blaabjerg, "Open-switch fault detection method of a back-to-back converter usingNPCtopology forwind turbine systems," *IEEE Trans. Ind. Appl.*, vol. 51, no. 1, pp. 325–335, Jan./Feb. 2015.

[24] Y. Jiao, F. C. Lee, and S. Lu, "Space vectormodulation for three-level NPC converter with neutral point voltage balance and switching loss reduction," *IEEE Trans. Power Electron.*, vol. 29, no. 10, pp. 5579–5591, Oct. 2014.