Original Research Paper

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Engineering

ROTOR SIDE AND GRID SIDE CONVERTERS FAULT IN DFIG BASED WECS

Arathy Raveendran	PG Scholar, Dept. of EEE, Sree Buddha College of Engineering, Pattoor, Alappuzha, Kerala
Chama R Chandran*	Asst.Professor Dept. of EEE, Sree Buddha College of Engineering, Pattoor, Alappuzha, Kerala *Corresponding Author
Reema N	Asst.Professor Dept. of EEE, Sree Buddha College of Engineering, Pattoor, Alappuzha, Kerala

ABSTRACT Wind energy is one of the renewable energy source used for the power generation. Nowadays doubly fed induction generators (DFIG) are commonly used, because of variable speed operation, power control and smaller converter capacity. DFIG based Wind energy conversion system (WECS) consists of Rotor side converter (RSC) and Grid side converter (GSC). These converters are made up of power electronics switches, so the chance of fault is more and this may lead to system damage. The DFIGs are also more sensitive to grid disturbance, so the detection of fault is more important. The DFIG based Wind energy conversion system is modeled and different fault such as switching fault is analyzed in MATLAB/SIMULINK software.

KEYWORDS : doubly fed induction generators, Rotor side converter, Grid side converter

INTRODUCTION

The number of wind turbines connected to the grid is increasing continuously; wind energy conversion system plays an important role in grid power in the future and requires more wind turbines and converters to stay in grid connected during the fault. The variable speed wind turbines connected through the power electronic converters are widely used [1]. Nowadays, the most commonly used wind turbine in the wind farm is based on doubly fed induction generator (DFIG).

The advantages of DFIG are: variable speed generation, decoupled control of active and reactive power and the improvement of power quality. The DFIG consists of both stator and rotor. The stator is directly connected to the grid and the rotor is connected to the grid through the power electronic converters such as grid side converter and rotor side converters. However wind turbines based on the DFIG are sensitive to the grid and converter related disturbances, such as short circuit, open circuit and ground fault in the terminals [2].

The RSC controls the active and reactive power from the stator to grid. The GSC controls the DC link voltage and allows the converter to generate or absorb the reactive power [3]. However, the stator and rotor of the DFIG are able to supply the power. The direction of active power depends up on the wind speed and generator speed. The main disadvantage of DFIG is its sensitivity to disturbance as the DFIG is directly connected to the grid through the windings.

In the DFIG based WECS, fault originate internally from the machine or externally from the grid. Internal fault may occur either in the turbine, gearbox, generator or power electronics converters. The power electronic converter plays an important role in wind energy conversion system for controlling and conditioning of output power from the wind energy. These power electronic devices undergo fault which affect the performance of the system, so the fault in the power electronics is considered as one of the major issue. The major fault associated with the converters in DFIG based WECs include short circuit fault, open circuit fault, and flash over with in the voltage source converter switches and fault in the DC link capacitors. The main causes of these fault includes driver circuit malfunction, auxiliary power supply failure, rapid change of voltage and opening or failure of the power switches in the converter. In this paper, first the DFIG based wind energy conversion is modeled and major switching faults in grid side converter; rotor side converter and DC link capacitor were analyzed in MATLAB/Simulink software.

MODELLING OF DFIG BASED WECS

The DFIG model is represented in synchronously rotating reference frame fixed to either the stator voltage or stator flux. The stator and rotor voltages in the dq reference frame can be expressed as,

$$V_{ds} = R_s i_{ds} + \frac{1}{\omega b}\frac{d}{dt}F_{ds} - \frac{\omega_s}{\omega_b}F_{qs} \quad (1)$$

$$V_{qs} = R_s i_{qs} + \frac{1}{\omega b}\frac{d}{dt}F_{qs} - \frac{\omega_s}{\omega_b}F_{ds} \quad (2)$$

$$V_{dr} = R_r i_{dr} + \frac{1}{\omega b}\frac{d}{dt}F_{dr} - \frac{(\omega_s-\omega_r)}{\omega_b}F_{dr} \quad (3)$$

$$V_{qr} = R_r i_{qr} + \frac{1}{\omega b}\frac{d}{dt}F_{qr} - \frac{(\omega_s-\omega_r)}{\omega_b}F_{qr} \quad (4)$$

The active and reactive power of stator and rotor are given by,

$$P_s = V_{ds}I_{ds} + V_{qs}I_{qs} \quad (5)$$

$$Q_s = V_{qs}I_{ds} - V_{ds}I_{qs} \quad (6)$$

$$P_r = V_{dr}I_{dr} + V_{qr}I_{qr} \quad (7)$$

$$Q_r = V_{qr}I_{dr} - V_{dr}I_{qr} \quad (8)$$

The torque of DFIG is given by,

$$T_g = \frac{3}{2}\frac{p}{2}\frac{1}{\omega_b}(F_{ds}i_{qs} - F_{qs}i_{ds}) \quad (9)$$

where, V is the voltage, I is the current, R is the resistance, p is the pole pair number, F is the flux linkage. The basic block diagram of DFIG is given in the Fig 1. The stator is directly connected to the grid and the rotor is connected to the grid through the converters such as rotor side converter, grid side converter and a back –back DC link capacitor.

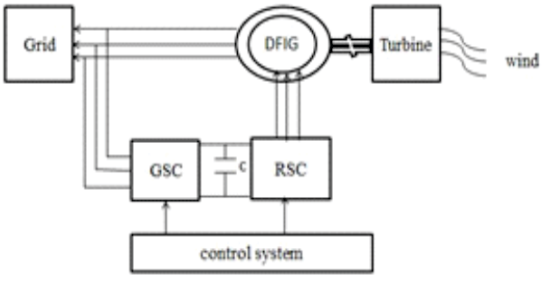


Figure 1: Basic block diagram of DFIG.

The MATLAB model of DFIG based wind energy conversion system is shown in Fig 2. The operation of the DFIG based wind energy conversion system is regulated by a control system, which includes control of RSC and GSC. Table -1 shows the specifications of DFIG based wind energy conversion system.

TABLE – 1 DFIG SPECIFICATIONS

Parameters	Value
Rated power	1.5 MW
Rated voltage	690V
Frequency	50Hz
Rated speed	1750rpm
No of poles	4
Stator resistance	0.01965pu
Rotor resistance	0.01909pu
Stator leakage inductance	0.0397pu
Rotor leakage inductance	0.0397pu
Magnetizing inductance	1.354pu

SIMULINK MODEL OF DFIG BASED WECS

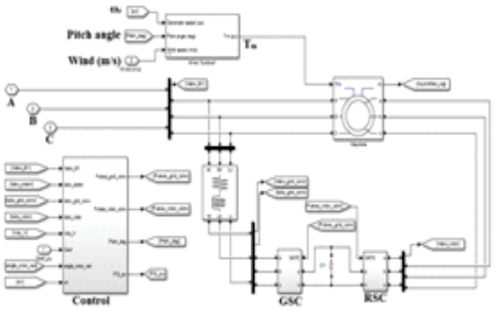


Fig 2: Simulink model of DFIG based WECS

SWITCHING FAULTS IN DFIG

Switching fault which mainly occur in the DFIG based wind energy conversion system are converter faults. These faults occur either in the turbine, gearbox, generator or power electronic converters, which include generator winding open circuit faults, winding insulation failure, semiconductor device failure, DC capacitor failure etc. More than 50% of the internal fault is due to the failure in the converter devices [4]. The faults in IGBT are mainly due to wrong voltage in IGBT gate, because of driver circuit malfunction, auxiliary power supply failure or rapid change of voltage; an inherent failure, which may occurred due to an overvoltage/avalanche stress or temperature overshoot.

The main faults in the converter devices are short circuit fault, open circuit fault and ground fault. These faults occur both in the switches as well as in the DC link capacitors. The grid side converter (GSC's) short circuit and open circuit fault, rotor side converter (RSC's) short circuit and open circuit fault, DC link capacitor open circuit, short circuit and ground faults are discussed below.

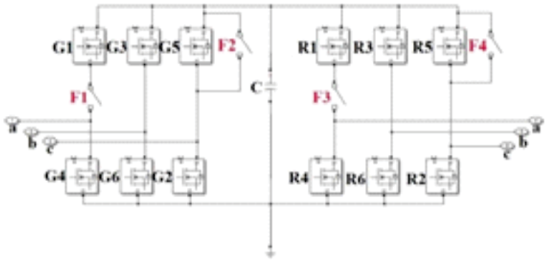
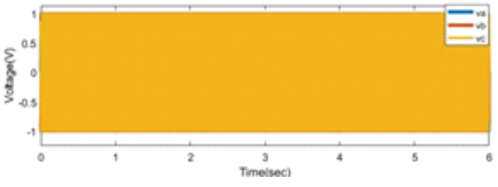


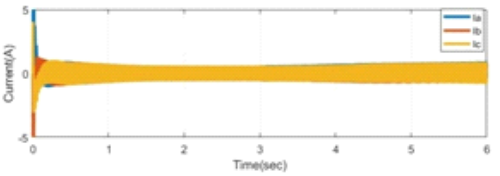
Fig 3: converter fault

SIMULATION RESULTS

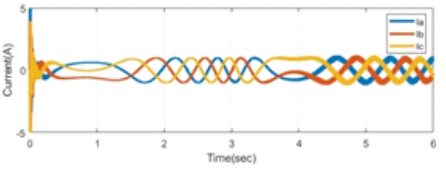
The DFIG based wind energy conversion system is analyzed in MATLAB/Simulink model. The graphs were plotted in per unit value. The stator voltage & current, the rotor current and DC link capacitor voltage under normal condition is shown in the Fig 4(a), (b) & ©.



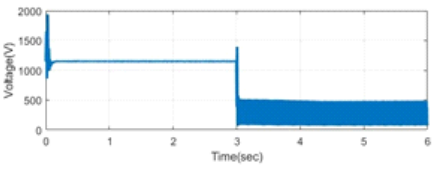
(a)



(b)



(c)



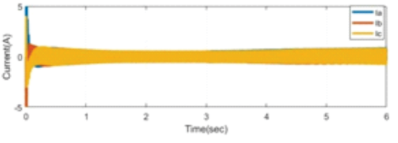
(d)

Fig 4: (a) stator voltage (b) stator current (c) rotor current (d) DC link capacitor.

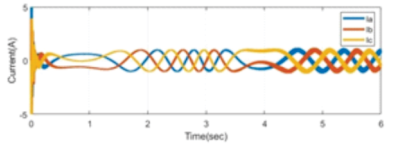
At starting the stator current and rotor current is increased from its normal value which will take some time to settle down as shown in Fig 4 (b) and ©. The DC link capacitor voltage value is maintained at 1150V as shown in Fig 4(d).

Grid side converter open circuit fault

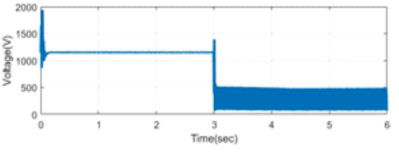
The main cause of open circuit fault in grid side converter is due to thermal stress and failure of gate driver circuit. The converter switch is opened for t=3sec. The stator and rotor currents are almost same like in normal condition, and is shown in Fig 5(a), (b) and © respectively.



(a)



(b)

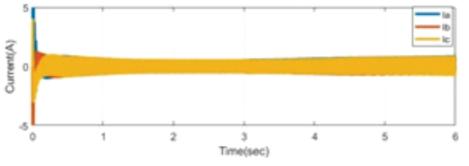


(C)

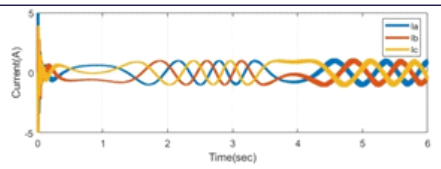
Fig 5: (a) stator current (b) rotor current© dc link capacitor under the fault grid open circuit.

Grid side converter short circuit fault

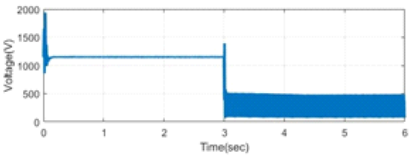
The short circuit fault in the grid side converter is due to voltage variation in the IGBT gate circuit and inherent failure. The switch is short circuited for time t=3sec, and stator current is increased as shown in Fig 6 (a). The rotor current is distorted and is shown in Fig (b). The DC link capacitor voltage is decreased to 100 V as shown in Fig ©.



(a)



(b)

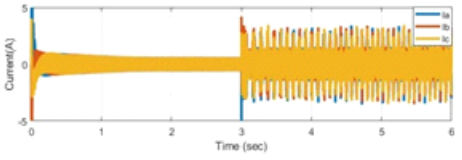


(C)

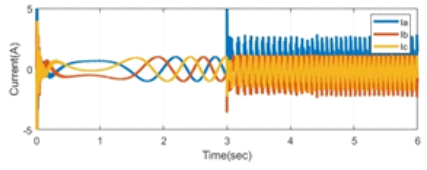
Fig 6: (a) stator current (b) rotor current© dc link capacitor under the fault grid short circuit.

Rotor side converter open circuit fault

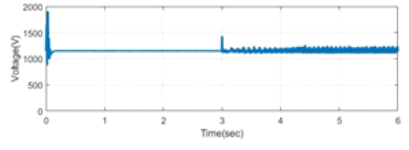
Rotor side converter switch is open circuited at t = 3sec. The stator current and rotor current is increased as shown in Fig.7 (a) and (b) respectively. The DC link capacitor voltage is distorted which is displayed in Fig. 7©.



(a)



(b)

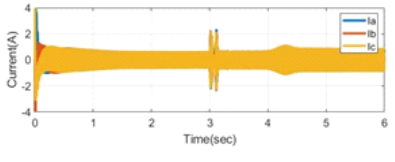


(C)

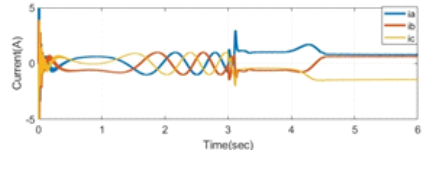
Fig 7: (a) stator current (b) rotor current© dc link capacitor under the fault rotor open circuit.

Rotor side converter short circuit fault

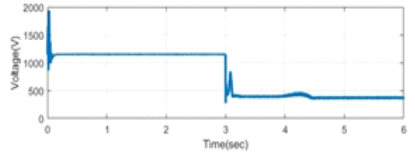
Rotor side converter switch is short circuited at t = 3sec. The stator current is increased as shown in Fig.8 (a) and the rotor current is distorted as shown in Fig 8(b). The DC link capacitor voltage is distorted as in Fig. 8©.



(a)



(b)



(C)

Fig 8: (a) stator current (b) rotor current© dc link capacitor under the fault rotor short circuit.

CONCLUSION

The DFIG based wind energy conversion system is modeled and simulated in MATLAB/Simulink software. Switching fault in grid side and rotor side converter is introduced by breaker switch, & various fault conditions such as short circuit & open circuit fault are simulated. From the analysis it was observed that this fault affect the performance of the DFIG based wind energy conversion system. Among this, RSC short circuit and GSC short circuit fault is more severe.

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