Ride-through of DFIG Wind Turbine Systems Using Energy Storage Unit

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Abstract

This paper deals with a ride-through technique of doubly-fed induction generator (DFIG) wind turbine systems using energy storage unit (ESU). By increasing the machine speed, some portion of the turbine power can be stored in the system inertia during grid faults. Also keeping the operation of rotor-side converter (RSC) and grid-side converter (GSC), the rotor current and DC-link voltage can be limited. The effectiveness of the proposed method is verified by simulation results for 2[MW] DFIG wind turbine system.

Key words: Ride-through, DFIG, wind power, ESU.

1. Introduction

The fast development of wind power generation brings new requirements for wind turbine integration into the network. One of the important demands is that a wind turbine has to provide fault ride-through (FRT) capability and stay connected during grid faults, satisfying the grid code shown in Fig. 1 [1]. The DFIG is a cost effective solution to handle variable speed operation since the converters are sized only for 20%-35% of the turbine power [2].

A uninterrupted operation method of a DFIG wind turbine during grid faults has been proposed [3]. In this scheme, the rotor-side converter (RSC) is blocked, and the rotor is short-circuited through a crowbar (an external resistor). A static synchronous compensator (STATCOM) [4] has been proposed to assist with the uninterrupted operation of a DFIG during grid faults.

In this paper, a method using ESU connected at DC-link side of back-to-back converter is proposed as shown in Fig. 2. The key of the method is to manage the energy produced by the wind turbine during the low-voltage events by keeping the operation of RSC and storing the energy into the ESU. Moreover, the generator power is controlled for the reduction of power delivered to the grid. A control strategy for the ESU composed of the power and current controllers is suggested, resulting in the improvement of the overall performance for ride-through. The validity of the proposed control algorithm is verified by simulation results.

2. DFIG modeling

2.1 DFIG modeling

A *d-q* reference frame is chosen to model the DFIG [5]. Adjustment of the *d-q axis* components of the rotor current controls the stator active and reactive power of the DFIG in which the slip angle frequency is used for transformation of rotor currents to d-q reference frame.

2.2 Control of back-to-back converters

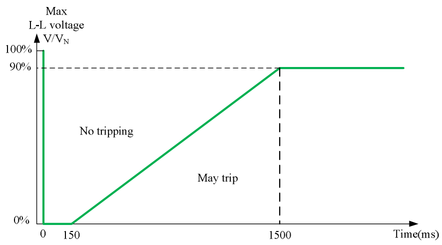

Fig. 1. Definition of FRT requirements in Germany.

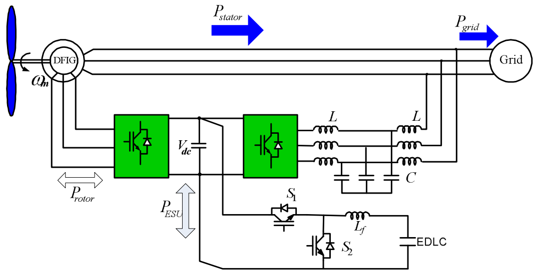

Fig. 2. DFIG wind turbine system with ESU.

For the control of the GSC, a cascaded control structure is applied which is composed of the inner current controller and the outer DC-link voltage controller [6].

For vector control of DFIG, the inner current control loop and the outer reactive and active power control loop are employed. The control block diagram of the DFIG wind turbine is shown in Fig. 3. The MPPT method is applied for the turbine power control, which gives the power reference of the DFIG at normal grid condition. At grid voltage sag, however, the MPPT control stops in order to reduce the turbine power extracted from wind. During this operation, the power reference of the DFIG is set lower than that in the case of presag, which leads to the increase of the system speed and some portion of turbine power can be stored in the system inertia.

3. Control of ESU

Under voltage sags, the grid can not absorb full power from the wind turbine. Thus, a portion of the turbine power is stored in the system inertia by increasing the system speed. Moreover, the GSC can not deliver the power from rotor side due to the reduction of grid voltage. So, in order to keep the DC-link voltage constant, the ESU is activated to absorb that power. For this purpose, the power controller is used in the main control loop with an inner current control loop for the ESU control as shown in Fig. 4. The power reference is given by the rotor power, P_r.

$$P_{ESU}^{*} = P_r \cdot \tag{5}$$

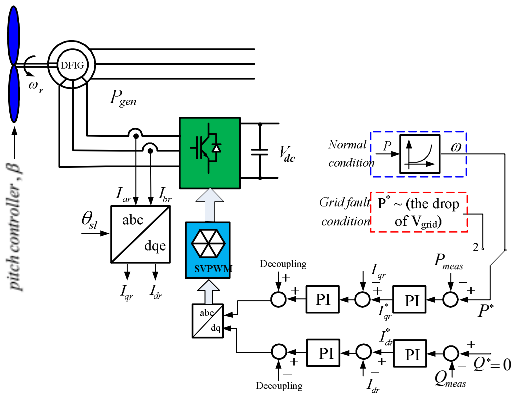

Fig. 3. Control block diagram of the DFIG.

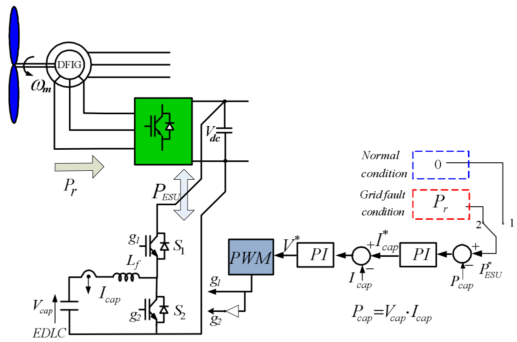

Fig. 4. ESU control.

In order to meet the requirements of the grid code, the ESU should have enough capability to absorb full power from rotor side in the worst case.

During the operation of the ESU, the voltage of the EDLC (electric double-layer capacitor) varies, where its capacitance, C, can be determined as

$$C=\frac{2\cdot E_{LVRT}}{\Delta V_{cap}\cdot V_{cap}^{rated}} \tag{6}$$

where V_{cap}^{rated} and ΔV_{cap} is the rated voltage and the voltage variation of the EDLC, respectively and E_{LVRT} is maximum energy determined from grid code during grid fault.

4. Simulation results

To verify the feasibility of the proposed scheme, PSCAD/EMTDC simulations have been performed for a 2[MW] DFIG wind turbine system. The grid voltage is 0.69[kV]/60[Hz] and has an unbalanced sag for 150[ms] duration. The switching frequency for both converters is 2.5[kHz]. The parameters of the DFIG are given in the Table 1.

Fig. 5 shows the response of DFIG wind turbine system under unbalanced grid voltage as shown in Fig. 5(a). The stator and rotor current of the DFIG are shown in Fig. 5(b) and (c), respectively which are limited within the allowable range by the reduction of generator power reference and the power absorbance of ESU. DC-link voltage of back-to-back converter is also kept near rating value as shown in Fig. 5(d). Fig. 5(e) shows the stator power which is decreased during grid faults, and the rotor power increases as shown in Fig. 5(f) since the system is accelerated by the turbine energy. Fig. 5(g) and (h) show the performance of the ESU in which the power and current of the ESU are shown, respectively. It is considered that the control performance is good.

5. Conclusions

This research has proposed the ride-through techniques for DFIG wind turbine systems using the ESU. By keeping the operation of the RSC, the system energy is managed and the wind turbine system stays connected to the grid during grid fault events. Moreover, the back-to-back converter is protected. The simulation results have verified the proposed method.

TABLE 1
PARAMETERS OF DFIG FOR SIMULATION

Rated power	2 [MW]
Stator voltage/frequency	690 [V]/60 [Hz]
Stator/rotor resistance	0.00488/0.00548 p.u.
Stator/rotor leakage inductance	0.0924/0.0995 p.u.
Moment of inertia	200[kg.m^2]

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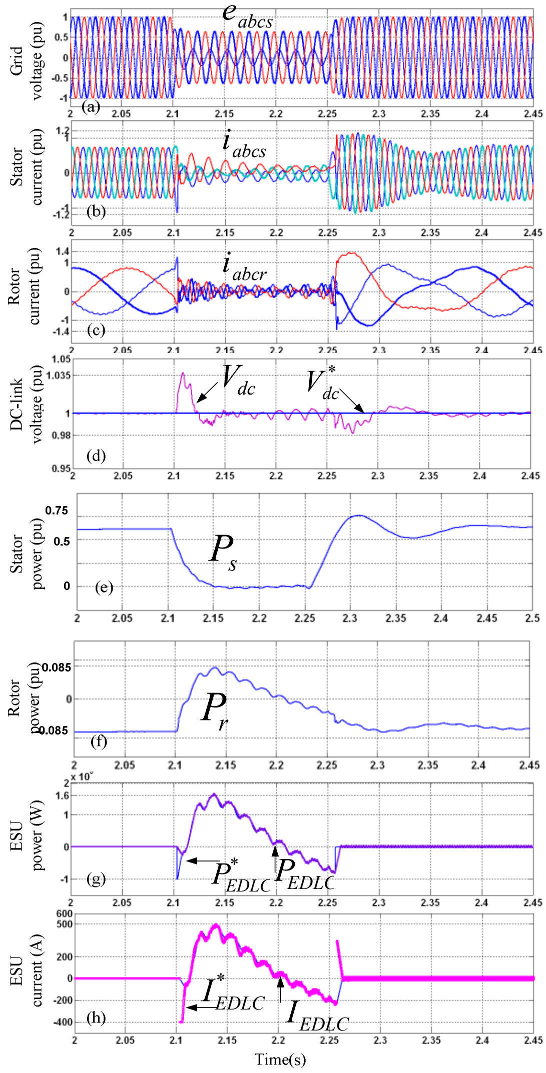

Fig. 5. The response of DFIG wind turbine system (a) Grid voltage, (b) stator current, (c) rotor current, (d) DC-link voltage, (e) stator power, (f) rotor power, (g) ESU power, (h) ESU current.

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