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Improvement of Fault Ride-Through Capability of Wind Turbine Driven DFIG Using Dynamic Voltage Restorer

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Abstract: This paper concentrates on the fault ride-through capability of a Doubly Fed Induction Generator (DFIG) - based wind turbine using a Dynamic Voltage Restorer (DVR). The voltage variations from normal operating range due to faults may lead to improper disconnection of wind turbines, so the DVR is included to protect wind turbines from voltage disturbances. DVR can compensate the faulty line voltage, while the DFIG wind turbine can continue its nominal operation as demanded in actual grid codes. In this paper, the Simulation results for a 2MW wind energy conversion turbine are presented for without DVR and with DVR for L-G fault (asymmetrical grid fault) and L-L-L fault (symmetrical grid fault). The results clearly show that there is improvement in stator voltage, stator and rotor currents, and active and reactive powers when wind turbine is driven with DVR.

Keywords: Doubly Fed Induction Generator, WECS, DVR, Asymmetrical and Symmetrical faults.

I. INTRODUCTION

As per progressive development of renewable energy systems especially, Wind Energy systems it is mandatory to have safe and stable operation throughout its service to avoid severe damages to the system and grid during any circumstances**.** In brief, considering the fault ride-through behaviour and also steady-state active power and reactive power production.

In this paper, the performance of DFIG based wind energy conversion system is investigated with and without DVR protection for L-G fault (Asymmetrical Fault) and L-L-L Fault (Symmetrical Fault). As per the Grid Codes, the WECS shouldn't be disconnected during any grid disturbances, answering this, in this paper, the fault ride through capability is obtained by the functioning of DVR during L-G fault (asymmetrical grid fault) and L-L-L fault (symmetrical grid fault). That means, the voltage dip which is caused during the faults will be stabilized or compensated by DVR, by injecting the necessary Reactive Power, thus, improving the Voltage Profile and further the Current Profile.

The simulation results show the improvement in the Stator, rotor, and active and reactive power responses. The DVR voltages are also shown in the simulation results for asymmetrical and symmetrical faults.

II. DFIG

Doubly Fed Induction Generator with back-to-back converter is widely used in wind energy generation systems because of high efficiency and independent control of active and reactive power. DFIG enables wind turbines to operate with various range of speeds which makes the system to use in wind turbines.

The investigated wind energy conversion system, as shown in Fig. 1, consists of the basic components like the wind turbine, a gearbox, a DFIG, and voltage source converter connected back-to-back with a DC link. A DC chopper is used to limit the DC voltage across the DC capacitor.

The converters connected back-to-back consists of a Rotor Side Converter (RSC) and a Load Side Converter (LSC), connected to the grid by a line filter to reduce the harmonics caused by the VSCs. DVR protection is included to protect the WECS from voltage disturbances.

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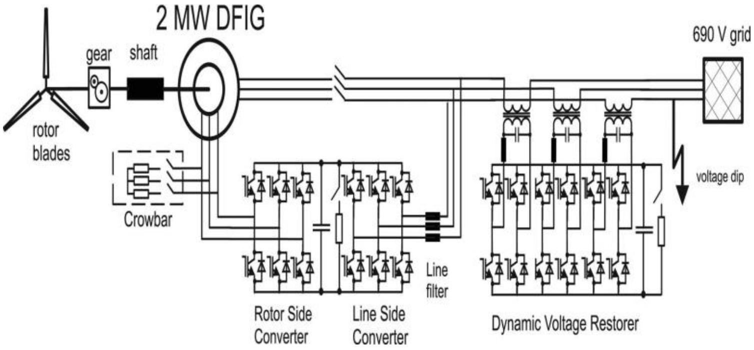

Fig. 1. Proposed DFIG based wind energy conversion system.

A. RSC-Control

Rotor Side Converter is a Voltage Source Converter (VSC). It supplies magnetization current to the rotor and controls the active and reactive power output independently by controlling d and q components of the rotor current.

So, RSC works in synchronization with speed of DFIG.

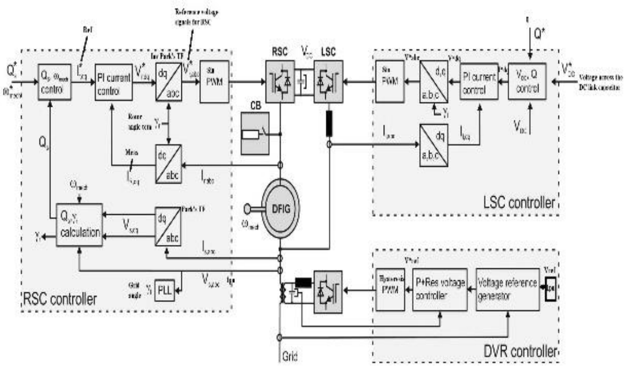

Fig. 2. Block Diagram of Proposed DFIG based wind energy conversion system.

Neglecting the stator resistive voltage drop, the stator output active and reactive powers are expressed as:

$$P_s \approx \frac{3}{2}\frac{L_h}{L_s} V_{sd} I_{rd}$$
$$Q_s \approx -\frac{3}{2}\frac{V_{sd}}{L_s}\left(\frac{V_{sd}}{\omega_s} + L_h I_{rq}\right)$$

thus, the stator active and reactive power can be controlled independently, controlling the *d*- and *q*-components of the rotor current based on above equations the outer power control loops are designed.

B.LSC-Control

The Load Side Converter is responsible for maintaining the DC bus voltage within certain limits by transferring the power from the rotor to grid. It also exchanges reactive power with the grid by either absorbing reactive power from the grid or exporting reactive power to the grid. LSC controls the DC voltage V_{DC} and provides reactive power support. So LSC works in synchronization with grid.

The line current I_l can be controlled by adjusting the voltage drop across the line inductance L_l giving the following dynamics:

$$V_s = R_l I_l + L_l \frac{dI_l}{dt}$$

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C. DVR

A Dynamic Voltage Restorer is a voltage source converter equipped with a line filter (usually LC type).

It is used to compensate the grid voltage disturbances. The DVR can compensate the faulty line voltage and enhance fault ride through capability of DFIG wind farms for a stable operation. Usually, a coupling transformer is used in series to the grid in order to correct deteriorated line voltages to reduce possible problems on generator. The rating of the DVR system depends mainly on the depth of the voltage fault that should be compensated.

$$P_{dvr} = \frac{V1-V2}{V1} P_{load}$$

where V_1 is the nominal and V_2 the faulty line voltage.

III. SIMULATION CIRCUIT

To show the effectiveness of the proposed technique, simulations have been performed using MATLAB/Simulink for a 2MW DFIG wind turbine system and a DVR, as shown in circuit. The simulation parameters are given in Table I. The control structure, as shown in Fig. 3, is implemented in Simulink.

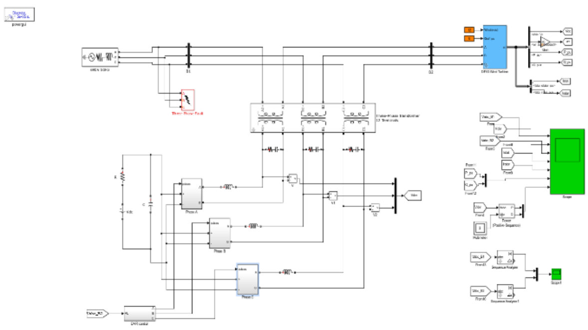

Fig. 3 Proposed System – Simulink Diagram.

TABLE-I

Simulation Parameters		
Symbol	Quantity	Value
U_{line}	low voltage level (phase-to-phase, rms)	690 V
ω_s	Line angular frequency	$2\ \pi$ 50 Hz
P_{DFIG}	Wind turbine rated power	2 MW
i	stator to rotor transmission ratio	1
n	Rated mechanical speed	1800 r/min
L_h	mutual inductance	3.7 mH
R_s	stator resistance	10 mΩ
$R_{crowbar}$	crowbar resistance	0.3 Ω

IV. SIMULATION RESULTS

A. Simulation of DFIG Performance without DVR Protection for Asymmetrical Faults:

Below Fig. 4 depicts the performance of DFIG at the stator side and at the grid side. It is clearly observable that without DVR there is change in stator's voltage and current so the DFIG generates a non-uniform power which leads to improper operation of wind turbine.

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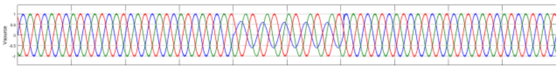
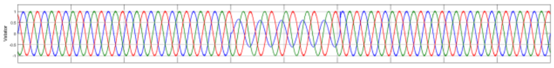
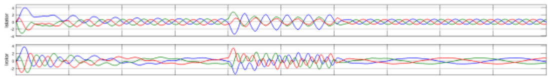


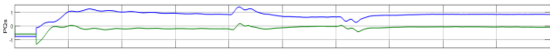
(a) Line Voltages



(b) Stator Voltages



(c) Stator and Rotor Currents

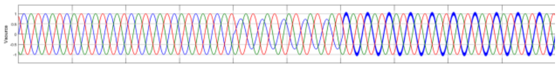


(d) Active and Reactive Powers

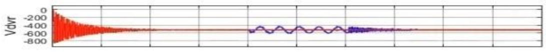
Fig. 4 Performance results of DFIG without DVR

B. Simulation of DFIG Performance with DVR Protection for Asymmetrical Faults (L-G):

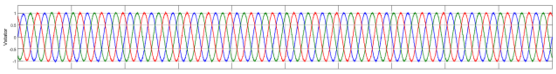
Below Fig 5 shows the simulation results for L-G faults in the grid. So, there is a change in one of the phase voltages of the line, to compensate this DVR injects voltage into the line so there is no change in stator voltage and current. Thus, the power generated by DFIG is uniform as shown.



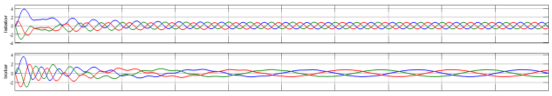
(a) Line Voltages



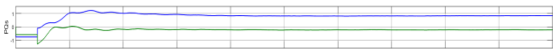
(b) DVR Voltages



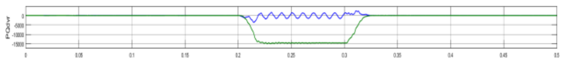
(c) Stator Voltages



(d) Stator and Rotor Currents



(e) Active and Reactive Powers



(f) Active and Reactive Powers of DVR

Fig. 5 Performance results of DFIG with DVR during L-G Fault (Asymmetrical Fault)

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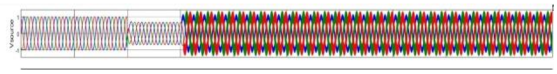
C. Simulation of DFIG Performance with DVR Protection for Symmetrical Faults (3-phase):

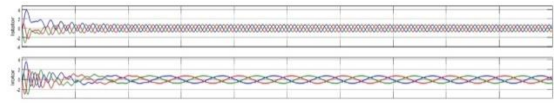
Below Fig 6 shows the simulation results for 3-phase faults in the grid. So, there is a change in three phase voltages of the line, to compensate this DVR injects voltage into the line so there is no change in stator voltage and current. Thus, the power generated by DFIG is uniform as shown.



(a) Line Voltages

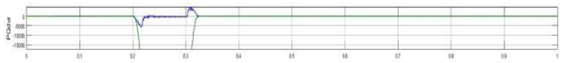
(b) DVR Voltages

(c) Stator Voltages



(d) Stator and Rotor Currents

(e) Active and Reactive Powers



(f) Active and Reactive Powers of DVR

Fig. 6 Performance results of DFIG with DVR during L-L-L Fault (Symmetrical Fault)

V. CONCLUSION

From the observations it can be concluded that the application of a DVR connected to a wind-turbine-driven DFIG, allows investigating uninterruptible fault ride-through of grid voltage faults. The DVR is compensating the faulty line voltage which can be symmetrical or asymmetrical so that DFIG Wind Turbine performs its operation without any interruption. Moreover, with the use of DVR it is added advantage for not being use of any protection methods. From the Simulation Results of a 2MW Wind Turbine under symmetrical and asymmetrical faults shows the effective working of proposed technique where continuous reactive power is not problematic. The results clearly show that the stator voltage, stator and rotor currents, and active and reactive powers are stabilized with DVR compared to without DVR.

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