“Effect of Grid Faults on Doubly fed Induction Generator Based Wind Turbines.”

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***Abstract:***

**The transient response is actually a critical dynamic characteristic of doubly fed induction generator-based wind turbines, especially in the presence of fast transient events, for example, faults in the power system. Here we present a direct rotor current-mode control (CMC) for the rotor-side converter of these induction generators, which is aimed to improve the transient response in relation to the dynamic performance achieved with the indirect CMC.** **The study considers two grid fault scenarios, with balanced and unbalanced voltages. This control scheme is compared in terms of performance and cost with the indirect CMC scheme**

**Key Words:**

**Current-mode control (CMC),Induction Generator, doubly fed induction generator (DFIG), grid fault, wind energy, wind turbine, wind power generation.**

**I.INTRODUCTION:**

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Fig. 1. Grid-connected DFIG-based wind turbine.

“Doubly fed electric machines are electric motors or electric generators that have windings on both stationary and rotating parts, where both windings transfer significant power between shaft and electrical system. Doubly fed machines are used in applications that require varying speed of the machine's shaft for a fixed power system frequency.” These advantages include high-power production, low mechanical stress, high-power quality, and low cost of the back to- back power-electronic converter [1]. A general diagram of the DFIG-based wind turbine is shown in Fig. 1.

Traditionally, a vector control approach is adopted for the rotor-side converter, which performs the tracking of the optimum operation point, limits the power in the case of high-wind speeds, and controls the reactive power exchanged between the wind turbine generator and the grid. Also, a vector control approach is used for the grid-side converter, which is responsible for both the regulation of the dc-link voltage and the injection of active power to the grid [2], [3].

**1I. INDIRECT ROTOR CMC**

*A .Balanced Grid Faults*

This method is also known as conventional method. In this part analytical procedure of the closed-loop behavior of the DFIG system using indirect CMC methods is given. Two current regulators for the rotor-side converter are considered: the conventional regulator and a regulator intended for unbalanced grid faults. The same steps are followed in both analyses: the open-loop model of the DFIG system is first formulated; second, the current regulator is written; and, third, by combining the open-loop mode and the control model, the closed-loop dynamic description of the rotor-side system is derived. [1]



Fig. 2. Conventional (indirect) current regulator.

 *Conventional Current Regulator*

 Fig. 2 shows the conventional current regulator for the rotor side converter. The regulator combines a proportional-integral (PI) controller with cross-coupling terms. The open-loop model of the DFIG system is represented, as usual, in the *d−q* reference frame. A synchronously rotating reference frame is used with the direct axis oriented along the stator flux position. In this way, the reference frame is rotating with the same speed as the stator voltage. Thus, the stator and rotor voltages can be expressed as given in equation (1) (2) (3) (4) [2] [3].

 (1)

 (2)

 (3)

 (4)

With

 (5)

 (6)

 (7)

 (8)

The inputs of the open-loop model are voltages and angular frequencies, and the outputs are currents. The stator voltage is given by the grid voltage, while the rotor voltage is supplied by the rotor-side converter. It is assumed in this study that the converters are sufficiently fast, so that they can exactly track the reference voltage. In this case, the rotor voltages are given by the rotor-side controller. [4][5]

 (9)

 (10)

The regulator combines a proportional-integral (PI) controller with cross-coupling terms

 (11)

 (12)

The cross-coupling terms are normally used to decouple the dynamics of *d* and *q* subsystems.

The closed-loop dynamic model of the rotor-side system can be derived by inserting (9)–(14) into (1)–(8), resulting in

 (13)

 (14)

Thus we see that the PI controller governs the dynamics of the rotor flux linkage, and as a consequence, the rotor current is only controlled indirectly.

*B. Unbalanced Grid Faults*

In this case, the open-loop DFIG system is decomposed in two separate models, which are represented with positive- and negative- sequence components, respectively. Fig. 3 shows the diagram of a current regulator intended for unbalanced grid faults.



Fig. 3. Indirect current regulator intended for unbalanced grid fault.

For the positive reference frame, the direct axis is fixed to the positive stator flux rotating at the stator angular frequency *ωs* , while for the negative-reference frame, the direct axis rotates at an angular frequency of *−ωs* . Thus, the stator and rotor voltage for the positive sequence model can be expressed as follows:

 (17)

 (18)

 (19)

 (20)

 (21)

 (22)

 (23)

 (24)

For the negative-sequence model, the stator and rotor voltage is given by

 (25)

 (26)

 (27)

 (28)

 (29)

 (30)

 (31)

 (32)

Both positive- and negative-sequence components are separately controlled with this conventional current regulator.

 (33)

 (34)

 (35)

 (36)

with

(37)

(38)

(39)

(40)

In this case, the closed-loop model of the DFIG system can be derived by inserting (33)–(40) into (17)–(32), resulting in

(41)

(42)

(43)

(44)

Again the PI controller governs the dynamics of the rotor flux linkage, and thus, the dynamics of the rotor current is only controlled indirectly.

**1II. DIRECT ROTOR CMC**

The previous analysis suggests that the transient response of the DFIG system can be improved with a direct control of the rotor current (instead of the rotor flux linkage). This section proposes direct current regulators for the rotor-side converter intended for grid faults.

*Direct Rotor Current Regulator*

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Fig. 3. Direct rotor current regulator

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Fig. 4. Diagram of the grid-connected DFIG-based wind turbine.

1. *System Description*

Fig. 4 shows the diagram of the wind power generation system considered in this study. The system consists of a 9-MW wind

turbine, a 25-kV distribution system, and a 120-kV grid. A 0.9-MVA filter and a 0.5-MW load are connected at the 575 V

generation bus.The simulation analysis was carried out in the MATLAB–Simulink software package. A transient model for the power generation system was developed including the DFIG machine, power converter, distribution system, and grid. The back-to-back power converter was represented, as usual, by equivalent voltage sources with the intention of reducing the computational time. A complete control system for the DFIG machine was also developed. The four rotor-side current regulators studied in this paper were implemented in order to compare their dynamic performance.

1. *Result:*

 Fig (5) and fig (6) shows the result of current of d-axis n q-axis. Fig. (7) Shows the result of flux linkage of d-axis and q- axis for the rotor side and fig. (8) shows results for active and reactive power for balanced faults.





Fig. 5 Reference Wave of idr and iqr for indirect control





Fig. 6 Rotor and Stator Current waveform for indirect control

 After performance evaluation, comparison of stator and rotor current with reference the current it can be observed that, the maximum overshoot and settling time is significantly high in the case of indirect rotor current control for grid faults. [1]





Fig. 7 Rotor Flux waveform for indirect control



Fig. 8 Active and Reactive power for indirect control

Fig (9) and fig (10) shows the result of current of d-axis n q-axis. Fig. (11) Shows the result of flux linkage of d-axis and q- axis for the rotor side and fig. (12) shows results for active and reactive power for unbalanced fault





Fig.9 Reference Wave of idr and iqr for indirect control





Fig 10 Rotor and Stator Current waveform for indirect control





Fig.11 Rotor Flux waveform for indirect control





Fig.12 Active and Reactive power for indirect control

CONCLUSION:

After simulation results we have examined that the dynamic performance of DFIG-based wind turbines in the presence of faults in the power system. The study first reveals that conventional current regulators for the DFIG rotor-side converter directly control the rotor flux linkage; thus the rotor current is only controlled indirectly The rotor-side controller, therefore, has poor reference-current tracking capability and the dynamic response of the rotor current to fast transient events is really poor. High overshoots and high-recovery time are clearly noted, which must be alleviated with protection elements in the rotor-side converter (for example, a resistive crowbar). Second, the paper proposes a method to develop direct rotor current control schemes. The proposed direct rotor current regulator significantly improves the transient response of DFIG systems during grid faults.

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