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IMPROVEMENT AND ANALYSIS OF THE TRANSIENT RESPONSE OF DOUBLY FED INDUCTION GENERATOR-BASED WIND TURBINES DIRECT CURRENT ROTOR MODE CONTROL

MR. SACHINKUMAR L. SARWADE
M.E. Scholar, (Electrical Power Systems), PVG's College of Engineering & Technology, Pune-09

PROF. MR. PARIKSHIT G. JAMDADE
Assistant Professor Department of Electrical Engineering, PVG's College of Engineering & Technology, Pune-09

ABSTRACT:

One of the vital and critically dynamic characteristics of the wind turbines is transient response. The performance of the induction generators used in such turbines is very important to control during transient states. In order to improve the performance of these generators, authors have proposed the current mode control (CMC). The proposed system is especially designed and implemented for the converters on rotor side. The scheme was implemented and its performance was compared with indirect CMC scheme. The performance of the implemented system is found suitable for the wind turbines and can provide the stability during the transient state.

KEY WORDS: Current-mode control (CMC), doubly fed induction generator (DFIG), grid fault, wind energy, wind turbine, wind power generation.

I. INTRODUCTION:

"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].

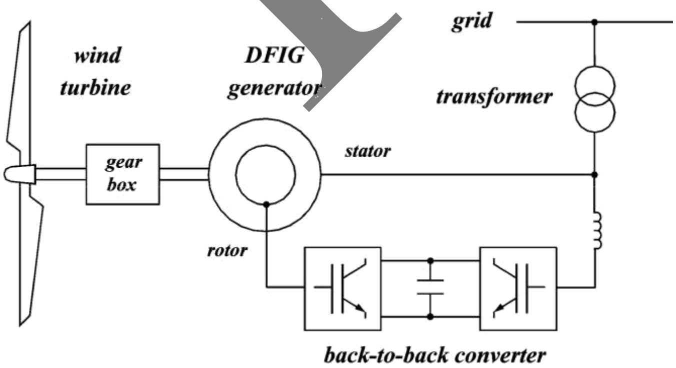

Fig. 1 Grid-connected DFIG-based wind turbine

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]. The main purpose of direct rotor current mode control for DFIG system during symmetrical grid fault i.e. for three phase to ground fault and voltage dip for the rotor side converter is to be concentrated [12].

In previous days rarely the vector control method is used for converter on rotor side, by using this method it is possible to track the optimum operation point, this method is used to limit the power in the case of high-wind speeds, and also controls the reactive power exchanged between the wind turbine generator and the grid. The reduction in voltage will results in reduction in efficiency of a system because the frequency will increase about double the grid frequency which then results in heating of dc-link capacitors [12-13].

Also, this method is used for the converter used at grid side, which is used for controlling the voltage across capacitor and the introduction of real power in to the grid. During the fault in a grid system, the working wind turbines which is depends on doubly fed induction generator is gets affected due to faults in the power system, even if fault is far away from the location of the wind turbine, this grid fault can cause a decrease in voltage at the connection point of the wind turbine and grid. The operation and control of doubly fed induction generator based wind turbines at steady state condition is now well known and has become most popular for the research work [12-18].

Here we observe the increase in the current which is flowing through the windings of stator and rotor of DFIG will be observed, which will then results in to the damage of the rotor side converter if we cannot connect the protection elements to ac-dc-ac converter.

The first solution was suggested for the protection of rotor side converter is that connecting crowbars across rotor winding which used for short circuiting the rotor windings. By using this method of protection, we will protect the converter but the wind turbine will be disconnected from the main grid system. Now a day these crowbar operation is modified by replacement of these crow bars with step by step switching and control of the voltage across capacitor [12-18].

Other solution suggested is that the connection of other different elements to the output terminal of the converter at rotor side to keep connected the wind turbine to the grid during the reduction in voltage due to fault in grid. In this situation, the turbine can be able to provide normal operation of the grid by means of supplying real and reactive power for supporting the frequency and voltage, same as that of normally used for working of power plants [3-6].

II. IMPLEMENTED MODEL:

The complete DFIG based grid connected wind power generation system is simulated in MATLAB Simulink for the following fault case of Symmetrical grid faults shown in Fig. 2.

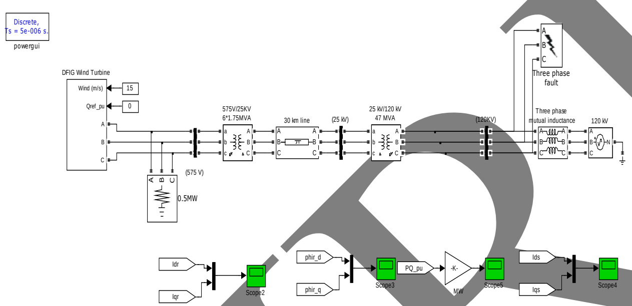

Fig. 2 Indirect and Direct current mode control scheme: Symmetrical Fault

III. SIMULATION RESULT OF DFIG SYSTEM USING MATLAB SIMULINK:

a. ROTOR CURRENT DURING SYMMETRICAL GRID FAULT:

Symmetrical grid fault is created at 0.2 sec and cleared at 0.6 sec and d-q current profiles for rotor currents are observed for indirect CMC and for direct CMC which is shown in fig 3 (a) and Fig.3 (b) respectively.

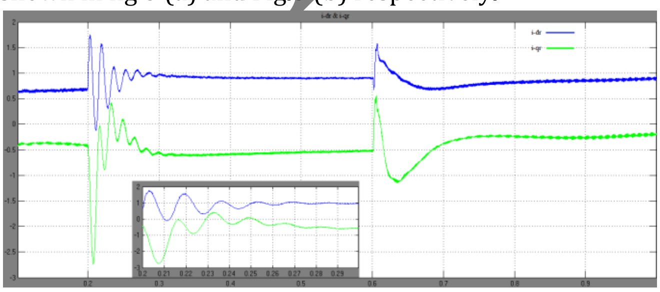

Fig 3(a): Rotor current for indirect method: Symmetrical Grid Fault

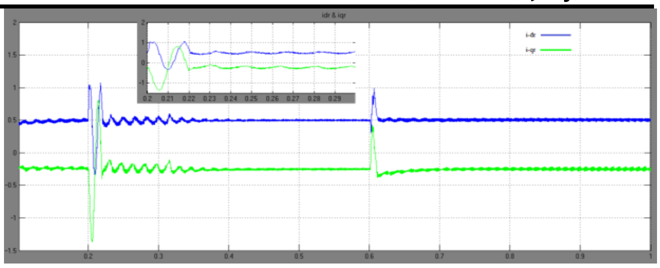

Fig 3 (b): Rotor Current for direct method: Symmetrical Grid Fault

b. ROTOR FLUX DURING SYMMETRICAL GRID FAULT:

For the same symmetrical fault of 0.4 sec from 0.2 sec to 0.6 sec d-q rotor flux profiles using indirect CMC and direct CMC are observed which are shown in fig 4 (a) and fig 4(b) respectively.

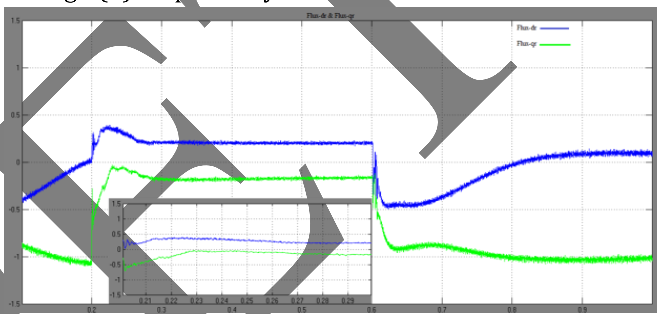

Fig 4(a) Rotor Flux for indirect method: Symmetrical Grid Fault

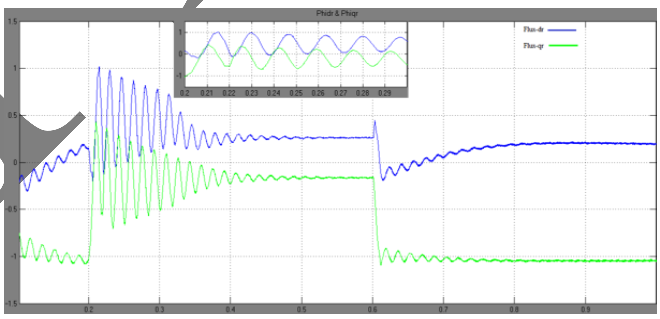

Fig 4 (b) Rotor fluxfor direct methods: Symmetrical Grid Fault

c. STATOR CURRENT DURING SYMMETRICAL GRID FAULT:

The d-q stator current profiles which are observed for indirect CMC and Direct CMC are show in fig 5 (a) and in fig 5 (b).

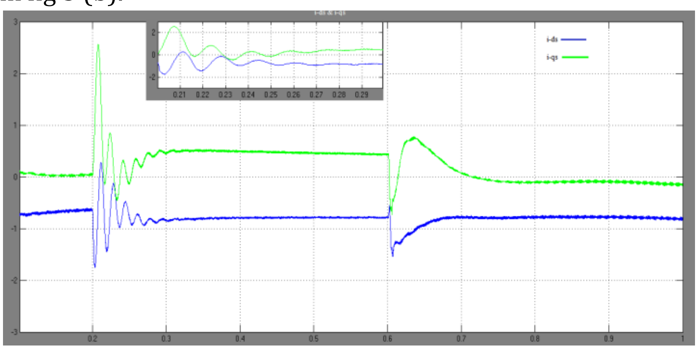

Fig 5 (a) Stator current for indirect method: Symmetrical Grid Fault

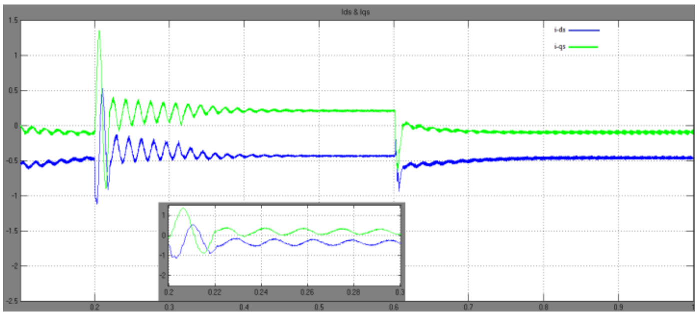

Fig 5 (b) Stator Currentfor direct method: Symmetrical Grid Fault

d. ACTIVE AND REACTIVE POWER DURING SYMMETRICAL GRID FAULT:

The observed active and reactive power profiles during symmetrical grid fault are shown for Indirect CMC fig 6 (a) and for direct CMC fig 6 (b)

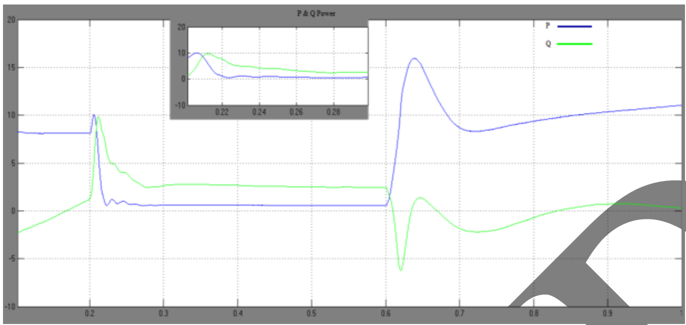

Fig 6 (a) Active and Reactive Power for indirect method: Symmetrical Grid Fault

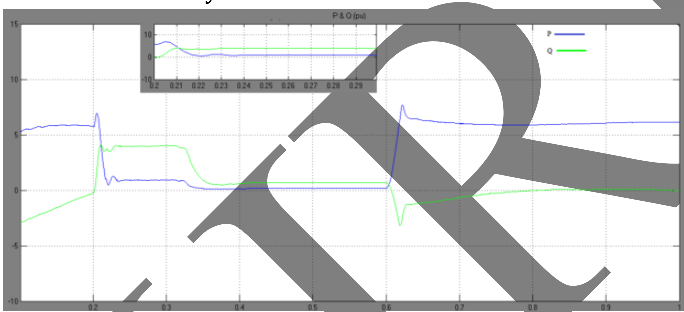

Fig 6 (b) Active and Reactive Powerfor direct method: Symmetrical Grid Fault

IV. WAVEFORM ANALYSIS:

1. Use of Direct Rotor Current mode control scheme at rotor side converter gives the noticeable reduction in current shoots for the rotor side thus proves to be useful in protection of the rotor side converter.
2. An increase in the rotor flux linkage can be seen in case of direct CMC method. Since increase in the flux linkage has less negative impact on the DFIG system it can be ignored.
3. Indirect Rotor current mode control proves to be successful in controlling the grid side converter current shoots since very less change can be seen in the grid side current by the implementation of Direct method so we can say that here current is controlled directly using Indirect method. Thus we are basically focusing on implementing this direct CMC method on the rotor side.
4. Direct method also controls the transient response of active and reactive power quite efficiently so that a large amount of power does not flow through the rotor converters since the converters are designed for a small amount of power flow ensuring no damage to the converters, less power losses, reduced costs of the converter-inverter arrangement, low cost power factor control implementation.

V. OBSERVED RESULTS DURING SYMMETRICAL GRID FAULT:

Table 1 d-q Rotor current transient response characteristics (Maximum over shoots) for Symmetrical grid fault

Control Scheme	Initial shoot		Fault shoot	
Parameters	i_{dr}	i_{qr}	i_{dr}	i_{qr}
Indirect Method	2	1.75	1.75	2.75
Direct Method	1.75	1.2	1.1	1.25
Reduction	0.25	0.55	0.65	1.5

Table 2 d-q Rotor flux transient response characteristics (Maximum Over shoots) for Symmetrical grid fault

Control Scheme	Initial shoot		Fault shoot	
Parameters	φdr	Φqr	φdr	Φqr
Indirect Method	0.5	0.7	0.4	0.5
Direct Method	0.6	1.1	1	0.6
Increase	0.1	0.4	0.6	0.1

Table 3 Stator current transient response characteristics (Maximum Over shoots) for Symmetrical grid fault

Control Scheme	Initial shoot		Fault shoot	
Parameters	ids	Iqs	ids	Iqs
Indirect Method	2	1	1.25	2.5
Direct Method	1.9	0.9	1	1.5
Reduction	0.1	0.1	0.25	1

Table 4 Active and Reactive power transient response characteristics for Symmetrical grid fault

Control Scheme	Initial shoot		Fault shoot	
Parameters	P(MW)	Q (Mvar)	P(MW)	Q (Mvar)
Indirect Method	14	-9	10	9.5
Direct Method	12	6	6.5	4
Reduction	2	-3	3.5	5.5

CONCLUSION:

In this study the variable speed wind generation system that is Doubly Fed Induction Generator (DFIG) system is simulated in MATLAB Simulink software. The working of the doubly fed induction generator based wind turbines during the symmetrical faults in a power system is simulated in MATLAB- Simulink software. While studying about DFIG based wind power generation system it is observed that current regulators used for the DFIG rotor side converter to control the flux linkage at rotor winding; so in this way the current through rotor winding is controlled by means of indirect method. The controller on rotor-side, therefore, does not have a good tracking capacity for reference-current and the dynamic performance of the current through rotor winding for events like fast transients actually poor. In the wave form high overshoots are observed very clearly, which should be required protection system in the rotor side converter for example connection of a resistive crowbar. In this project a method for developing direct current control method for rotor side converter is explained. The closed loop dynamic system of the DFIG based wind turbine system is studied to detect proper terms called as cross coupling terms; these terms are used for transformation of the flux linkage and this flux is controlled by means of current control. The method used here is successfully studied in presence symmetrical three phase faults and voltage reductions; hence it provides the control configuration of two direct current regulators of rotor. After studying this entire thing we considered the method of direct current control for rotor side controller is used to improve the transient response of DFIG systems during grid faults significantly with control implementation complexity to indirect current regulators.

NOMENCLATURE:

d, q Subscript denoting synchronous *d*– *q* axis.
is, ir Stator, rotor current.
kp, ki Proportional, integral control gain.
Lm Mutual inductance.
Ls, Lr Stator, rotor self-inductance.
pi Superscript denoting proportional-integral (PI) terms.
Rs,Rr Stator, rotor resistance.
s, r Subscript for stator, rotor.
vs , vr Stator, rotor voltage.
* Superscript denoting control reference value.
+, − Superscript for positive, negative components.
σ Leakage factor.
ωs, ωr Stator, rotor angular frequency.
ψs, ψr Stator, rotor flux linkage.

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