Power Control in a Doubly Fed Induction Machine

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***Abstract*—**This paper proposes a direct power control for doubly-fed induction machine for variable speed wind power generation. It provides decoupled regulation of the primary side active and reactive power and it is suitable for both electric energy generation and drive applications**.** In order to control the power flowing between the stator of the DFIG and the network, a decoupled control of active and reactive power is synthesized using PI controllers.The obtained simulation results show the feasibility and the effectiveness of the suggested method

***Keywords*—**Doubly fed induction machine , decoupled power control , vector control ,active and reactive power, PWM inverter

I. Introduction

The wind energy systems using a doubly-fed induction generator (DFIG) have some advantages due to variable speed operation and four quadrant active and reactive power capabilities compared with fixed speed induction. Some investigations by using predictive functional controller [1] and internal mode controller [2], [3] have satisfactory power response when compared with the power response of PI but it is hardly to implement one due to the predictive functional controller and internal mode controller formulation. Another possibility to doubly-fed power control. can be made by using fuzzy logic [4], [5]. These strategies have satisfactory power response although it involves relatively complex transformation of voltages, currents and control outputs among the stationary, the rotor and the synchronous reference frames. The direct power control was applied to the DFIG power control and it has been presented in [6], [7], [8].This scheme calculates the required rotor controlling voltage directly based on the estimated stator flux, active and reactive power and their errors. In [6] the principles and the implementation of DPC is made with hysteresis controllers and variable switching frequency. In [7], [8] the principles of this method are described in detail and simulations results have been presented with variable and constant switching frequency respectively. Moreover, the conventional DPC complicates the AC filter design because of its variable switching frequency. An alternative to direct power control is the power error vectorcontrol [9]. This strategy is less complex and obtains similarresults to direct power control. To improve the power response, to eliminate the torque ripple and to protection of rotor-side converter under grid voltage sags a proportional control with anti-jamming control was proposed in [10]. This control has satisfactory power response and eliminate the rotor current overshoot in voltage sags when the loop of torque control is applied, although power and rotorcurrents results were shown only in fixed speed operation.We present in this paper a direct power control , it results a good decoupling control between active and reactive power, it achieves high accuracy and fast dynamic power response.

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II. Description And Modeling Of DFIM

The proposed system is shown on figure 1, it is constituted by two pulse width modulation inverters supplying separately the stator and the rotor of the machine [11]

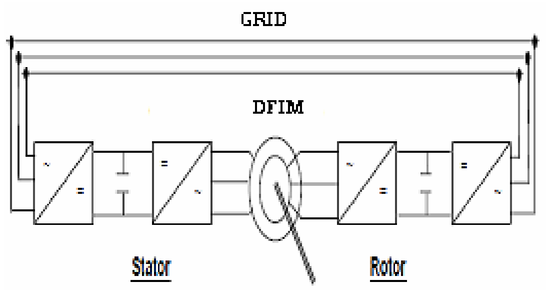

Fig .1 DFIM supplied by two PWM inverters

We choose three levels PWM for both stator and rotor inverters, it is constitute of three arms, every one has four switches formed by a transistor and a diode as shown in figure 2

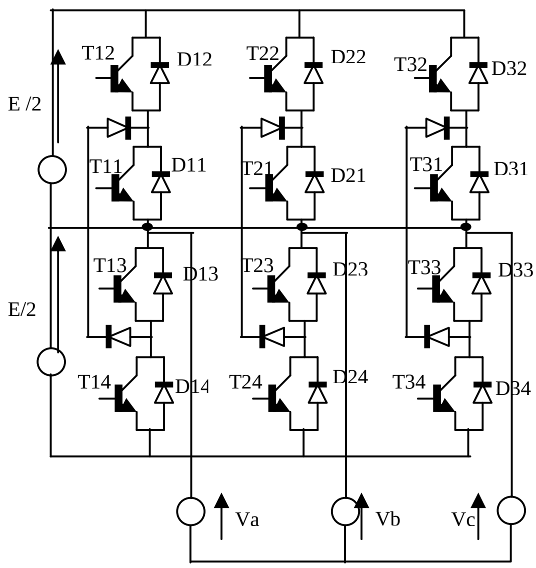

Fig .2 General diagram of a three level PWM inverter

The simple voltages are obtained starting from the following conditions:

If ($V_{réf} = V_p$) and ($V_{réf} > 0$)

$=> V_K = + E/2$

If ($V_{réf} = V_p$) and ($V_{réf} < 0$)

$=> V_K = -E/2$

If $V_{réf} = V_p$ $=> V_K = 0$

With

$V_{réf}$: reference voltage standard;

V_p: carrying;

V_K: potential of the node K.

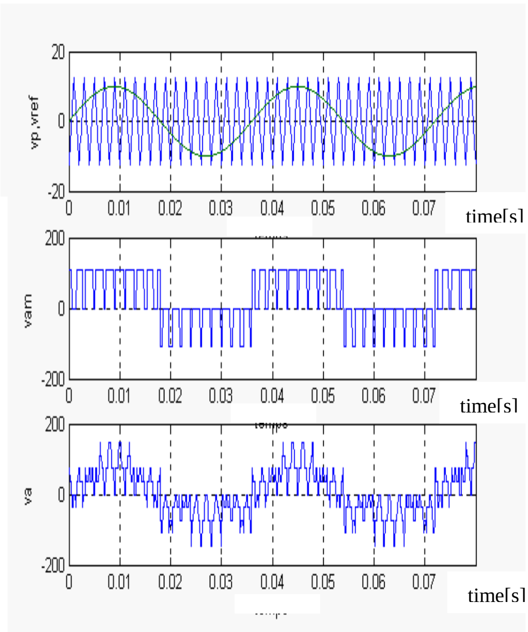

Fig .3 Carrying voltage, simple voltage and phase voltage

Stator and rotor voltages of the machine after Park transformation are given by [12]:

$$\begin{cases} Vds = RsIds + \frac{d}{dt}\psi ds - \frac{d\theta s}{dt}\psi qs \\ Vqs = RsIqs + \frac{d}{dt}\psi qs + \frac{d\theta s}{dt}\psi ds \end{cases} \quad (1)$$

$$\begin{cases} Vdr = RrIdr + \frac{d}{dt}\psi dr - \frac{d\theta r}{dt}\psi qr \\ Vqr = RrIqr + \frac{d}{dt}\psi qr + \frac{d\theta r}{dt}\psi dr \end{cases} \quad (2)$$

Stator and rotor fluxes are given by:

$$\begin{cases} \psi ds = LsIds = MIdr \\ \psi qs = LsIqs + MIqr \\ \psi dr = LrIdr + MIds \\ \psi qr = LrIqr + MIqs \end{cases} \quad (3)$$

Mechanic equation is given by:

$$Cem = Cr + J\frac{d\Omega}{dt} + f\Omega \quad (4)$$

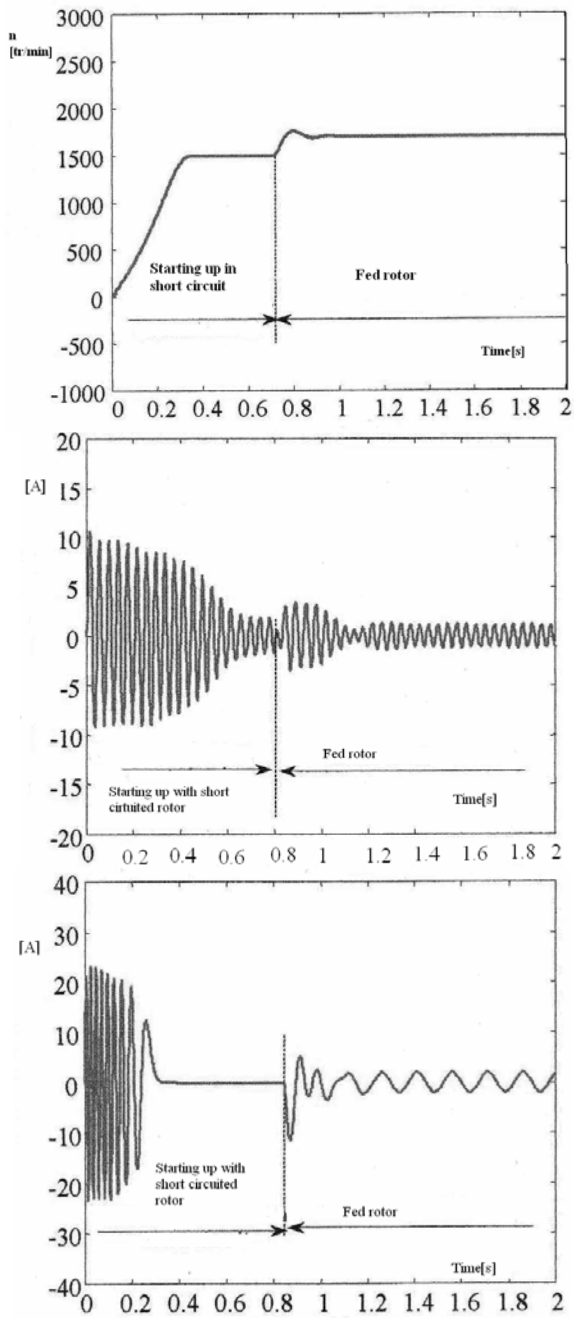

Fig .4 Speed, stator current and rotor current during starting up of the machine

III. Control Strategies

By orienting rotor flux towards d-axis, and stator flux towards q-axis. Conventionally, the d-axis remains reserved to magnetizing axis and q -axis to torque axis, we obtain

$$\psi sq = \psi s\ ,$$
$$\psi rd = \psi r\ ,$$
$$\psi sd = \psi rq = 0\ .$$

Then the developed torque can be written like this

$$\text{Cem} = Dc\psi s\psi r\ ,\ Dc=pM/\sigma LsLr$$

Vectoriel diagrams before and after flux orientation are shown as follows [13]

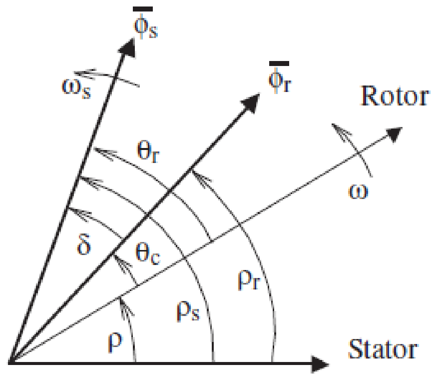

Fig .5 DFIM flux relative armature position

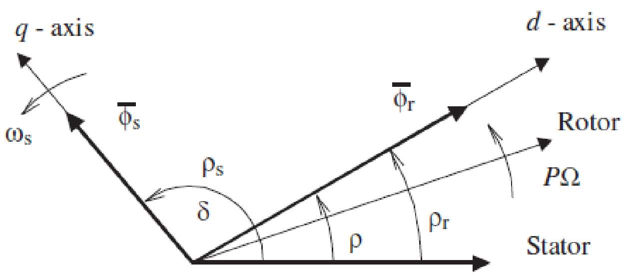

Fig .6 DFIM vectorial diagram after orientation

The stator active and reactive powers can be written as:

$P=V_{ds}.I_{ds}+V_{qs}.I_{qs}$
$Q=V_{qs}.I_{ds}-V_{ds}.I_{qs}$

After all calculations we can draw up this plan:

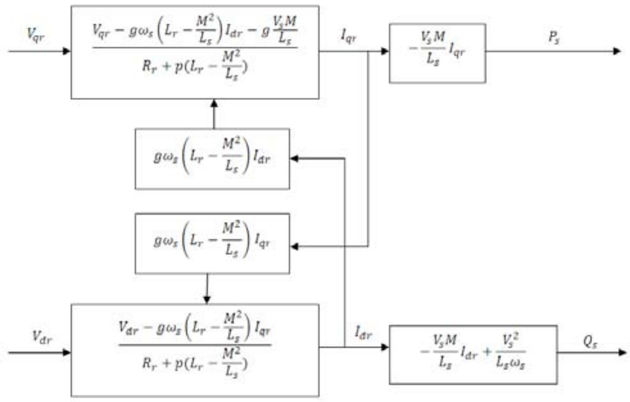

Fig. 7 Block diagram of the DFIG

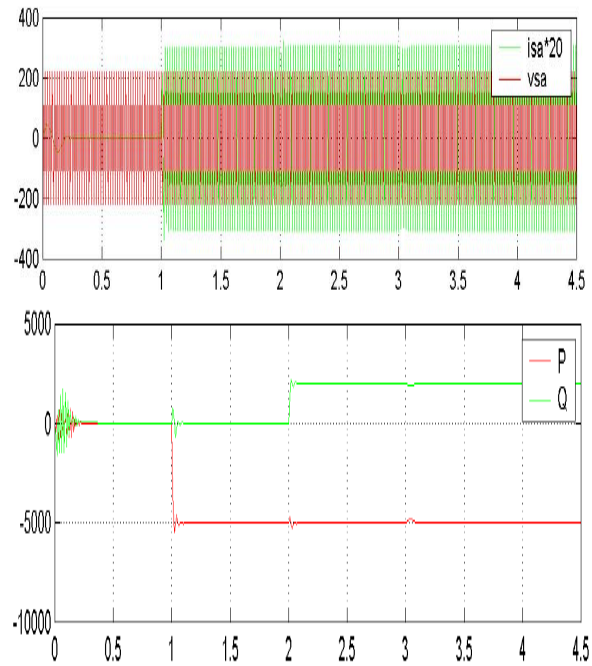

Fig. 8 Stator voltage and current, active and reactive power

IV. Results Analysis

Figure 3 shows the carrying voltage, simple voltage and phase voltage of the three levels inverters used. Figure 4 presents speed, stator current and rotor current in the starting up of the machine ,until 0.8s the machine starts with rotor in short circuit , after the rotor is fed by the inverter. In figure 8 we can see stator voltage and current, and active and reactive power, at time equal to 1s, we forced the active power to -5Kw, the reactive power did not react, also we give a level of 2 KVA to the reactive power and the active one did not react, we can conclude that we effectively made a decoupling between both powers. It can be said that this strategy in addition of its simplicity, shows good results.

V. Conclusion

We present in this paper a simulation of a doubly fed induction machine fed with two pulse width modulation inverters , based on d-q modeling. Access to the stator and rotor windings is one of the advantages of the wound rotor induction machine compared to the conventional squirrel-cage machine, consequently the doubly fed induction machine offer the several possible combinations for its control. A double flux orientation was presented , Since the fluxes are used like control variables, the machine fluxes must be maintained at acceptable level especially during the transient regimes. In addition of that , we made a success to decouple the active and the reactive power. This control development has enabled us to highlight several interesting aspects for further study on the whole power wind production. It is obvious that direct method is easier to implement than the indirect one.

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