

## Research Article

### DFIG Harmonic Current Controlling with the Grid Low Harmonic Voltage

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**Abstract:** This study presents a vector control strategy based on stator harmonic current closed-loop, it adds individually the control loop about of each stator harmonic current to restrain the stator harmonic current, in order to meet the THD criteria. The control strategy of restraining the harmonic current presents the design of the stator harmonic current restrains the current controller. It influences the rotor voltage of the stator harmonic current restraining strategies.

**Keywords:** Harmonic, strategy, stator, THD criteria, vector

#### INTRODUCTION

DIFG is the current mainstream wind turbine wind generator, when the wind grid-connected, may produce harmonic voltage. Harmonic voltage have a serious impact on the grid, many studies show that, if the rational harmonic suppression voltage generating will improve grid power quality. Many research institutions at abroad to carry out research in this area, but in the effect of harmonic voltage is not very obvious. If starting from the generation mechanism of wind turbine internal, reasonable reduce grid harmonic, fundamentally improve the parallel efficiency.

In order to restrain the low harmonic component of the stator current, it adds the stator harmonic current restraining loop on the conventional vector control strategy. The terminal voltages of the DFIG are asymmetrical, the electromagnetic torque of the generator would drop and the rotor speed would increase. In order to keep the rotor speed, the rotor side converter can increase the rotor current (Mardia, 2009). During the grid short circuit, such as hyper synchronous, the terminal voltages of the DFIG are asymmetrical; the active power from the grid side converter would decrease (Van Doorn *et al.*, 2000). The grid voltage is more asymmetrical and the power difference is more, the maximum direct voltage is more (Bowers *et al.*, 2011). If the capability of the grid side converter is enough, the voltage tolerance of the direct voltage controlling circuit would rise, the power of the grid side converter would increase and then with the grid side converter controlling, the direct voltage would decrease to the reference voltage (Wang, 2012).

#### MATERIALS

Figure 1 is the schematic diagram of control strategy; it can selectively restrain the stator harmonic current.

$\theta_1$  is the grid angle,  $i_{sdq}$  is the stator d axis (or q axis) current,  $\bar{i}_{sdq5}$  and  $\bar{i}_{sdq7}$  are 5th and 7th the stator harmonic DC current component of the d axis (or q axis),  $i_{sdq5}^*$  and  $i_{sdq7}^*$  are 5th and 7th the stator harmonic d axis ( or q axis) the current instruction. A is the DFIG grid-connected detection and control loop, B and C are stator harmonic restrain control loop. Because the grid-connected control loop bandwidth is limited, is unable to restrain the stator current 5th and 7th harmonic current, then there are the 5th and the 7th stator harmonic current control loop (Johan *et al.*, 2005). It can reduce stator current distortion and corresponding active power, electromagnetic torque oscillation of the grid 5th and 7th harmonic voltage (Tabesh and Irvani, 2006).

Just like the stator 5th harmonic current control loop, it uses the rotating coordinate transformation to transform the 5th harmonic current component from the alternating current component into direct current component, transform the stator fundamental current component to the 300 Hz AC component. In order to ensure low pass filter has the attenuation ability on the part of AC component, the low pass cutoff frequency of the filter is designed as 40Hz. The Butterworth low-pass filter can filter out the fundamental AC component, get the stator 5th harmonic currents DC component  $\bar{i}_{sdq5}$ , it is compared to the 5th harmonic current instruction  $i_{sdq5}^*$ , it is the PI controller without static error correction on AC component. The rotor

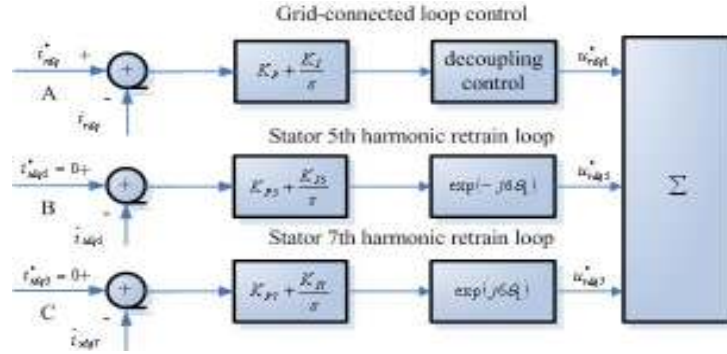


Fig. 1: Schematic diagram of harmonic current suppressing control

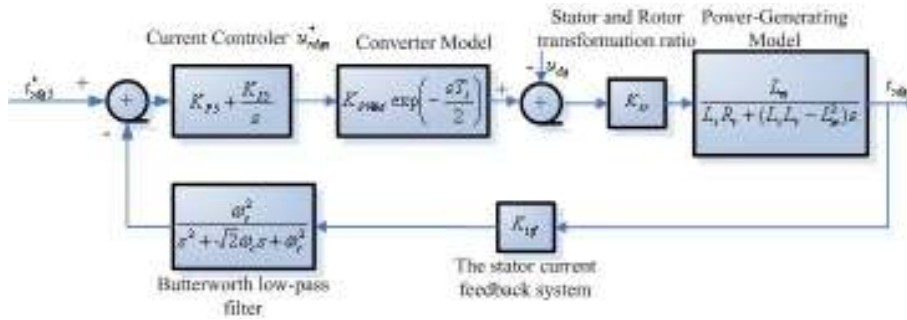


Fig. 2: Control diagram of the 5th stator current restraining control loop

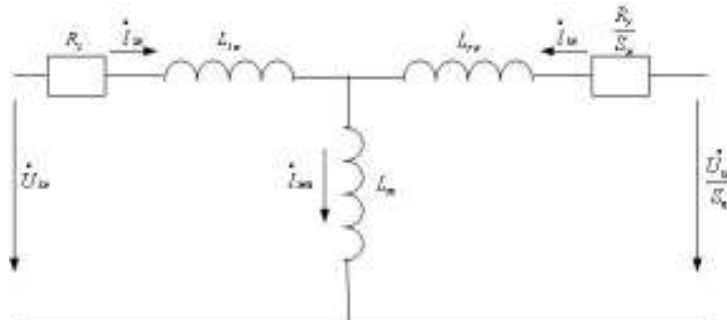


Fig. 3: Steady-state circuit of DFIG

voltage control instruction  $u_{rdq}^*$  restrain the stator 5th harmonic current to 0.

$$\frac{isdq5(s)}{u_{rdq5}(s)} = \frac{L_m}{L_s R_r + (L_s L_r - L_m^2)s} \quad (1)$$

**The Design of the stator harmonic current restrains the current controller:** In the stator harmonic current restraining control has a very important step; it is the design of current controller parameters in the control loop. The harmonic current restraining is only an auxiliary control, can not affect the normal grid-connected main control circuit, therefore, the harmonic current restraining loop bandwidth is to be far less than the grid-connected control loop bandwidth.

As the stator 5th harmonic current restraining control loop, in order to design the current controller, it is the first that getting the DFIG model transfer function from the rotor voltage to the stator current in the 5th rotating coordinate system, ignoring the decoupling phase, the transfer function is:

Therefore, Fig. 2 is the control circuit diagram of the 5th harmonic current restraining control loop of stator.  $\omega_c$

Figure 2 shows the stator 5th harmonic restraining loop before the compensation and after the compensation. The control loop cross-over frequency is 10 Hz (less than 200 Hz); the phase margin is 72°.

The DFIG practical electromechanical transient model is based on the stator magnetic linkage oriented control strategy; the stator magnetic linkage oriented control strategy can control the active and reactive power decoupling in the rotor converter model.

The DC side voltage sampling frequency notch function with dual current control strategy can join PLL on notch filter for real-time correction according to the

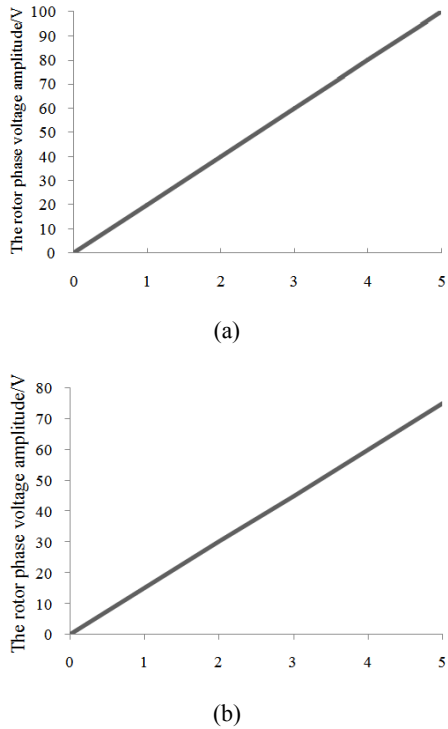


Fig. 4: Relationship between grid harmonic voltage and modulation voltage of converter; (a): The 5<sup>th</sup> harmonic ratio/%; (b): The 7<sup>th</sup> harmonic ratio/%

grid frequency fluctuation. The simulation results show that when the grid has asymmetric fault and frequency fluctuation the strategy has better dynamic adjustment performance than the positive, negative sequence dual current control strategy.

## METHODS

**The influence on rotor voltage of the stator harmonic current restraining strategies:** The steady state equivalent circuit of DFIG in nth harmonic voltage is shown in Fig. 3.

In order to restrain the nth harmonic current  $I_{sn}$  of the grid harmonic voltage  $U_{sn}$  on the stator, the component of voltage should be added on the rotor side, offset the effect of  $U_{sn}$ . The formula of the rotor phase voltage is from the analysis of the DFIG steady state circuit:

$$U_{rn} = \left| \frac{U_{sn} [jn\omega_1 s_n (L_{r\sigma} + L_m) + R_r]}{k_{sr} jn\omega_1 L_m} \right| \quad (2)$$

## RESULTS

The rotor phase voltage amplitude varies with the harmonic voltage rate. The relationship between the rotor phase voltage amplitude and harmonic voltage will be helpful to find the way to control the grid harmonic. The voltage will be reasonable adjustment of

wind turbines has inhibitory effect on grid harmonic; control terminal voltage current can be effectively implemented in the harmonic control.

For the 5th harmonic grid voltage, when  $f_r$  is 60Hz the rotor voltage is the most high requirement, as shown in Fig. 4a. For the 5th harmonic grid voltage, when  $f_r$  is 40Hz the rotor phase voltage is most high requirement, as shown in Fig. 4b.

As the Fig. 4, the rotor phase voltage amplitude varies linearly with the harmonic voltage rate.

## DISCUSSION

This study only studies the grid harmonic and wind turbine electrical parameters, it did not give way to complete harmonic suppression, but by controlling the terminal voltage to adjust the harmonic current. We need to improve the overall quality of the harmonic power, also need to carry on deep research to effectively suppress the power grid.

## CONCLUSION

Effective control of harmonic voltage effectively suppress power grid fault wind turbine rotor voltage, not only improve the wind turbine power quality, as if also effectively suppress the harmonics presents theoretical basis.

## ACKNOWLEDGMENT

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