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Analysis of The DFIG Structure and Its Grid-connecting Mode

Siyu Pan[1, a]
[1]North China Electric Power University, Beijing, 102206
[a]alanncepu@foxmail.com

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Abstract. This paper firstly demonstrated the working mode of variable speed constant frequency in DFIG and gave introduction to the structure of excitation converter. Then it explained the main circuit topology and control mode of grid-side converter. Third, this paper analyzed the grid-connecting mode of DFIG from grid-connected principles, Comparison of two common grid-connected methods and new types of parallel control strategy. At last we drew a conclusion.

Introduction

Double fed induction generator(DFIG) has been widely used in renewable energy generation. The stator directly connects with power grid. Through ac-dc-ac rotor excitation converter the stator controls the frequency, phase position, amplitude of rotor current, which is finally decisive to the output power of the stator side. DFIG has independent rotor exciting winding and it can regulate power factor independently. The system has good dynamic performance.

Analysis of the DFIG structure

Demonstration of variable speed constant frequency working mode. Assume that the stator and rotor windings are all symmetrical. The number of pole-pairs is p, according to the theory of rotating magnetic field, when three-phase symmetrical voltage is inflicted on the three-phase symmetrical windings of a stator and the three-phase symmetrical current exists in windings, it creates a rotating magnetic field in the air gap of electrical machinery. The speed of this filed is n_1, which is known as synchronous speed, the relationship between n_1, f_1, p is as the formula below:

$$n_1 = \frac{60f_1}{p} \tag{1}$$

Similarly, when the three-phase symmetrical current, whose frequency is f_2, is inflicted on the three-phase symmetrical windings of a rotor. The rotating magnetic field speed relative to the speed of rotor can be shown as:

$$n_2 = \frac{60f_2}{p} \tag{2}$$

From the formula we can know that: change f_2 means changing n_2.Thus,we assume n_1 is the synchronous speed , corresponding to f_1=50Hz,what we are supposed to do is maintain $n \pm n_2 = n_1 = \text{constant}$,then we can insure f_1 is also consistent, which is called constant frequency.Now we assume the slip ratio of DFIG is $S=\frac{n_1-n}{n_1}$,then the current frequency flowed in the rotor three-phase windings of the DFIG should be:

$$f_2 = \frac{pn_2}{60} = \frac{p(n_1-n)}{60} = \frac{pn_1}{60} * \frac{n_1-n}{n_1} = f_1 * s \tag{3}$$

The structure of excitation converter

Instruction. Converter is made of INU(machine side converter),intermediate dc bus, ARU(grid-side converter).both converters use PWM modulation mode, the large capacitor in dc bus can storage energy and filter harmonic, making dc voltage amplitude stable. As is shown below:

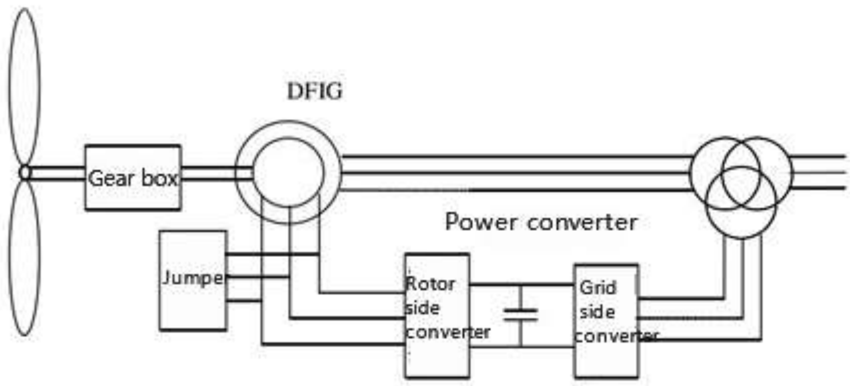

Figure 1. The structure of excitation converter

Grid-side converter. Usually adopt three-phase PWM voltage rectifier. The control strategy can be divided into direct current control (closed loop) and indirect current control (open loop). The open loop system has no feedback and dynamic response is slow, which is inappropriate for high sensitivity demand in modern control system. Closed loop system has a good dynamic response and it's used widely. Direct current control can still be divided into linear control and nonlinear control, linear control includes current hysteresis control, state feedback control, current control by PI adjustment and so on; nonlinear control can be divided into fuzzy control and neural networks control and so on. The main circuit topology is displayed below:

Machine-side converter. The circuit topology is similar to which of the grid-side converter, usually adopt three-phase PWM voltage circuit. The final circuit is shown below:

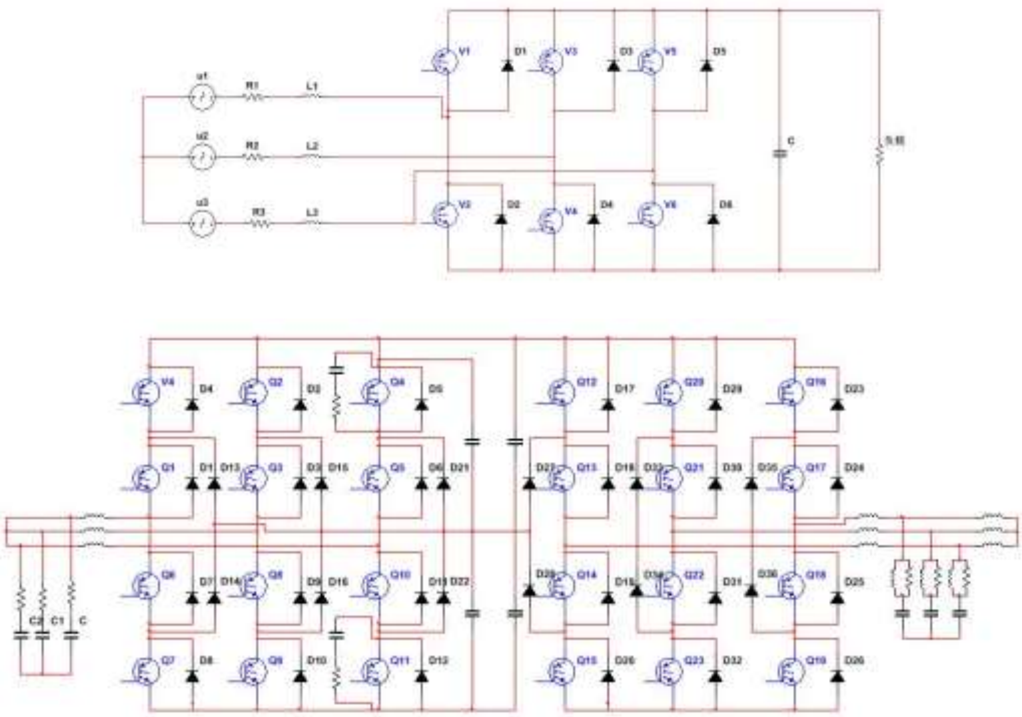

Figure 2. Three-phase PWM voltage circuit

Analysis of DFIG's Grid-Connecting Mode

Grid-Connected Principles. Before grid-connecting, we need to make the adjustment before grid connecting to meet the grid condition: The stator voltage must be strictly the same with network voltage in amplitude, frequency and phase position so that generator can get into normal running status rapidly. The main request for grid connecting is to limit the transient current of the generator, avoiding the excessive current shock to the grid, which can result in the collapse of voltage and destroy of fan unit.

Comparison of Two Common Grid-Connected Methods. Because DFIG us ac as excitation, when connecting to the grid we can control the field current by changing network voltage, load current and engine speed. This method can control the stator voltage accurately, which is also called" flexible cutting-in". The common control method is:

No-load cutting-in: according to the frequency, phase position and amplitude of the grid, control excitation to ensure that the stator floating voltage is exactly the same with the grid voltage in any revolving speed before connecting grid. The control structure block diagram is displayed below:

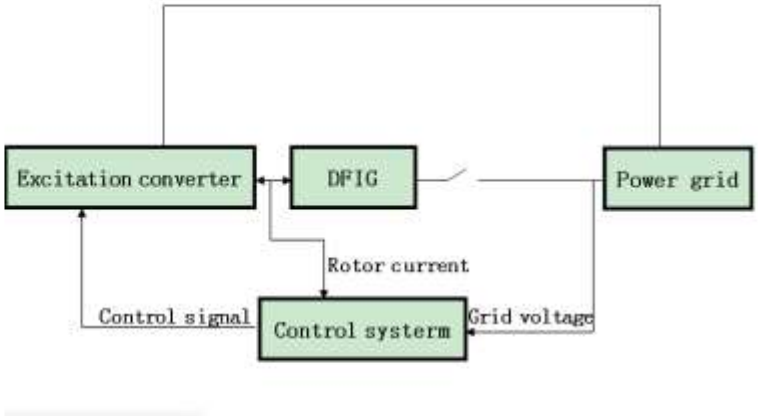

Figure 3. The control structure block diagram

Load cutting-in: According to the grid voltage, stator voltage, current information to control excitation system. The feature is that the control information collected is not only from the grid, but from DFIG stator voltage as feedback as well. Therefore, the regulation is more delicacy, but the weakness is that it's more complicated. The control structure block diagram is displayed below:

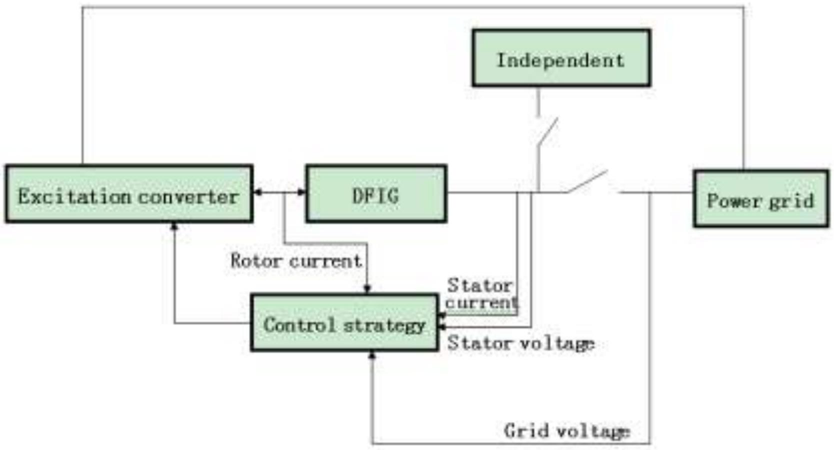

Figure 4. The control structure block diagram

New types of parallel control strategy.

As the reference shown, there is a control method of grading grid-connecting. Firstly, compensate for initial error of rotor position, only use rotor current closed loop control at this time. Later at the stage of stator voltage setting up, adopt directional vector control of grid voltage. At the connecting grid stage, use the closed-loop power control of stator side. These measures are to insure the smooth transition of reference value of rotor current.

Another reference shows that we can use MPDPC model to predict the active power and reactive power at next moment. By comparing given power and feedback power we can find the minimum error of voltage vector as the best non-zero vector. And thereby realize the aim that power pulse and rotor harmonic are both little.

Conclusion

DFIG rely on its peculiarity of “flexible cutting-in”, collect data to control by two means (no-load, load). These years, to decrease surge current and power pulse, we adopt more advanced control strategies and these methods effect significantly.

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