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풍력발전 계통연계를 위한 매트릭스 컨버터의 개발

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Development of Matrix Converter for Grid-Connected Wind Power Generation

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Abstract - As a renewable power source, wind power generation has been research interest for many years. And power electronic converters have been developed and applied in variable speed wind turbines. This paper presents the basic development and implementation of space-vector modulated three phase AC-AC matrix converter for variable speed wind power system. Basic matrix converter operation is described, where a new bidirectional switch structure with commutation circuit is used. Finally, experiment results of basic converter operation are shown.

1. Introduction

With the increasing need for electric power consumption, wind power generation has recently experienced a rapid growth around the world. Wind power is renewable energy, and generates no pollution. Wind turbines can be installed near load centers and urban areas, thus simultaneously eliminating the need of high voltage transmission lines running through rural landscapes[1].

Recently, variable speed operated wind turbines are being widely developed and installed. Fig. 1 shows a diagram of a variable speed wind turbine with a doubly-fed induction generator (DFIG). As seen in Fig. 1, the system consists of a DFIG and a power electronic AC-AC converter. Such grid-connected variable speed wind power system has some advantages compared with fixed speed wind turbines, among those are possibilities to reduce stresses of the mechanical structure and acoustic noise reduction. And with the help of power electronic converter, it is possible to control active and reactive power[2].

The power electronic converter plays a key role in variable speed operation of wind turbines. Conventionally, an AC-DC rectifier and a DC-AC inverter back-to-back connected are used for variable speed control purpose, while a three phase AC-AC matrix converter may be a better choice for the advantages of no large DC link energy storage element and compact structure. The matrix converter is able to generate variable output voltage with controlled input power factor, it has been the researching interest in variable power conversion, motor driving and regenerative power application. This paper presents the development and implementation of a three phase to three phase space-vector modulated matrix converter. Converter circuit and basic operation are described. A new bidirectional switch structure is used for commutation purpose. Finally, experimental results support the validity of the design and development [3].

2. Matrix converter operation

2.1 Converter circuit

Fig. 2 shows the power circuit of a three phase AC-AC matrix converter. As seen in Fig. 2, the matrix converter contains a three by three array of bidirectional switches which directly connect the three phase output ports with the input ports. Inductor set (L_{sa}, L_{sb} ,L_{sc}) and capacitor C_s form the input filter. A simple RL load is connected for basic test purpose. Two diode bridges connect the output to input for over voltage clamping purpose.

2.2 Bidirectional switch structure and commutation

The key element in a matrix converter is the fully controlled forced-commutated bidirectional switch. And practical commutation operation between switches is very important for safety consideration and proper converter operation. A new bidirectional switch structure with snubber circuit is proposed for commutating action. Fig. 3 shows the structure of the utilized bidirectional switch. As seen in Fig. 3, the bidirectional switch mainly consists one commercial IGBT module and one commercial diode module, and a simple RC snubber is connected as commutation aid. This structure requires no extra sensing information and allows dead-time commutation. Resultantly, the operation is very stable, reliable and robust.

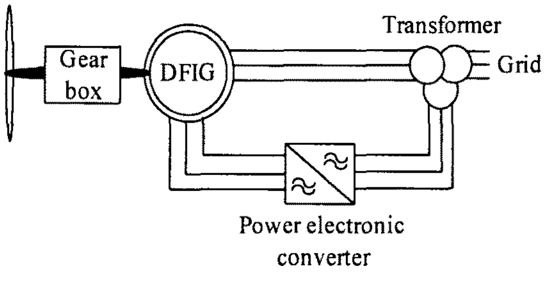

Fig. 1 Variable speed wind turbine with a DFIG and power electronic converter

In order to explain the commutation procedure, it is enough to look into a two phase to single phase matrix converter shown in Fig. 4. In Fig. 4, the two bidirectional switches have the structure of Fig. 3.

According to the input voltage polarity and output current direction in Fig. 4, there exist 4 commutation cases. The commutation procedure in these 4 cases will be almost the same, so the condition when the input voltage and output current are both positive is dealt as an example. Fig. 5 shows the commutation modes and the practical current path is shown in bold line in Fig. 5. The gating signal for IGBTs in Fig. 5 is shown in Fig. 6.

In Fig. 5, Mode I is the initial mode, S_1, S_2 are on and S_3, S_4 are off. Load current flows through D_3 and $S3$. Then the dead time begins and Mode II is the circuit state. Since all the IGBTs are turned off, the load current flows through the

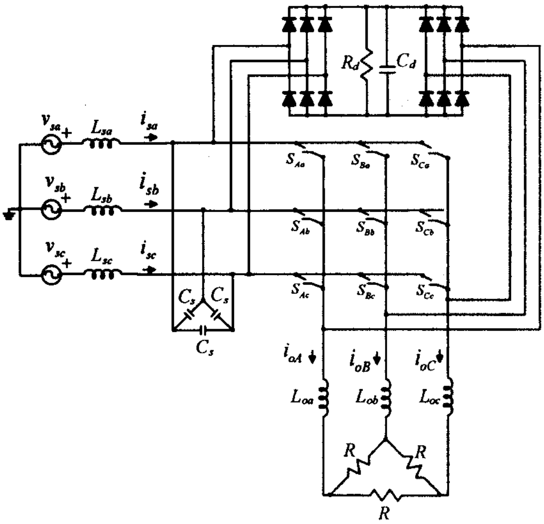

Fig. 2 Three phase AC-AC matrix converter power circuit

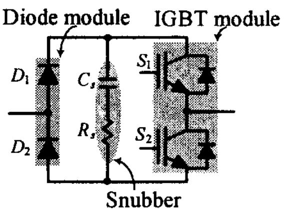

Fig. 3 Bidirectional switch structure with snubber

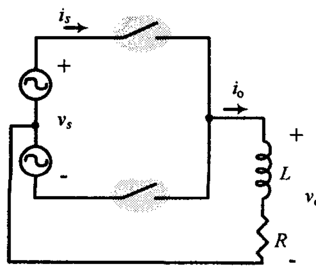

Fig.4 Two phase to single phase matrix converter

snubber circuit and charge C_{s2}. When dead time ends and S_1, S_2 are turned on, the circuit enters Mode III, in which the load current commutates to D_1-S_1 loop and C_{s1} discharges through R_{s1}, C_{s2} will finally charge to V_s. After the snubber capacitors finish charging and discharging, Mode IV is the final circuit state. Then the commutation ends.

2.3 Space vector modulation method

The space vector modulation method in [3] is applied to generate the control signal for 9 bidirectional switches. Fig. 7 is the block diagram of the modulator. As shown in Fig. 7, the main control algorithm is performed by a digital signal processor (DSP). The three phase input voltages are sensed and read by analog to digital converters (ADC) of DSP to perform three phase discrete phase lock loop (PLL) function, and the PLL output information will be used to generate the input current vector command. With the output voltage vector command given, the modulator will generate and output 9 bit control signal for each of the 9 bidirectional switches to complex programmable logic device (CPLD). After the CPLD performs dead-time generation, the gating signal will be transferred to IGBT driver through optic fiber link to turn the IGBTs on or off.

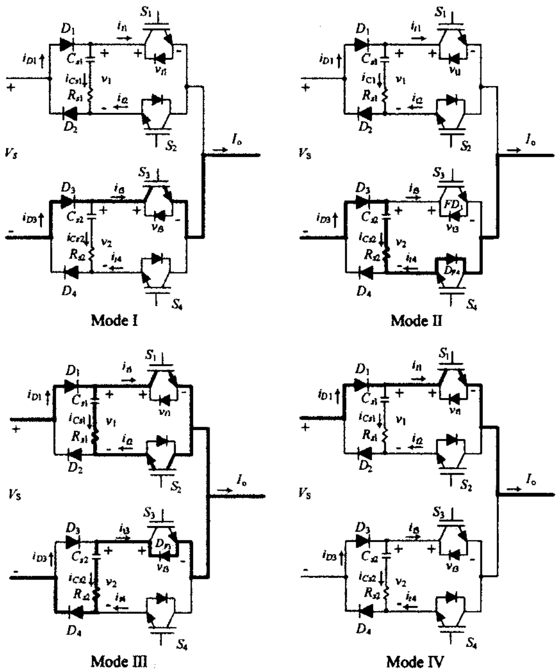

Fig. 5 Commutation procedure

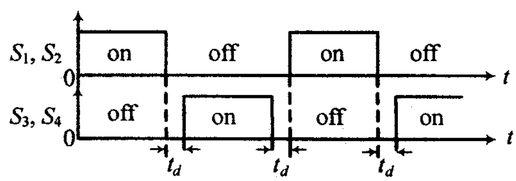

Fig. 6 IGBTs' gating signal

3. Experiment

An experiment setup is made to implement the three phase AC-AC matrix converter. The circuit parameters are given as follows:

$V_{s,M}$=100V, L_s=10μH, C_f=65μF, C_s=0.22μF, R_s=10Ω, L_o=6mH, R=7Ω, t_d=1μs, f_s=5kHz.

where $V_{s,M}$ is the input line to line magnitude, t_d is the dead time and f_s the switching frequency.

The IGBT module used to construct the bidirectional switch is CM200DY-12E from MITSUBISHI and the diode module is DSEI 2x 101-12A from IXYS. And for controlling purpose, the DSP is TMS320F2812 from Texas Instruments and CPLD type is EPM7128SLC84-15 from Altera.

Fig. 8 shows the experiment waveforms when the output frequency f_o is 30Hz and the output to input voltage ratio m=0.6. Fig. 9 gives another set of waveforms when f_o=120Hz and m=0.6. It can be seen from Fig. 8 and Fig. 9 that the matrix converter operates well and the utilized bidirectional switches structure facilitates the commutation robustly and stably.

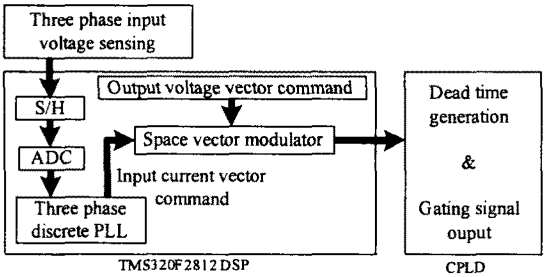

Fig. 7 Modulator block diagram

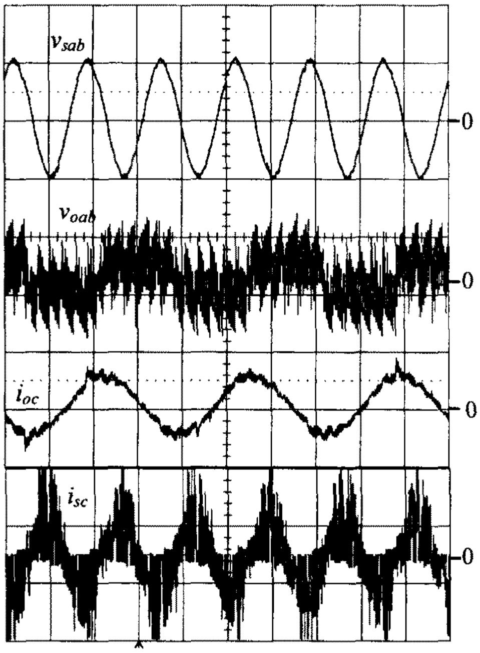

Fig. 8 30Hz experiment waveforms
v_{sab}(100V/div, 10ms/div),v_{oab}(100V/div, 10ms/div)
i_{oc}(5A/div, 10ms/div),i_{sc}(5A/div, 10ms/div)

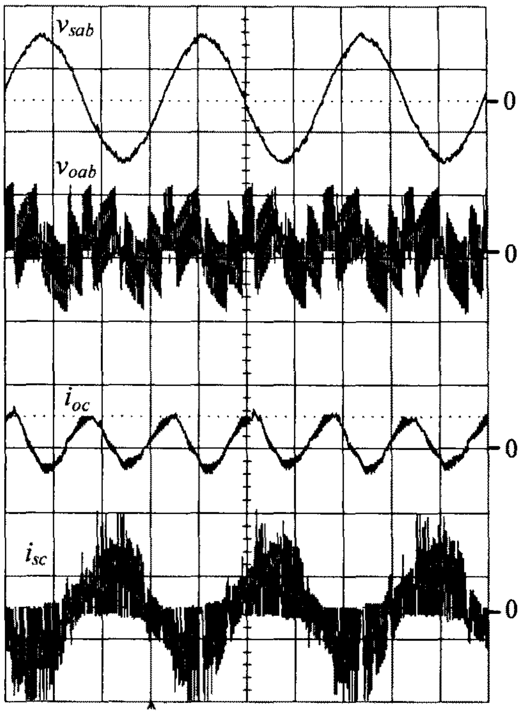

Fig. 9 120Hz experiment waveforms
v_{sab}(100V/div, 5ms/div),v_{oab}(100V/div, 5ms/div)
i_{oc}(5A/div, 5ms/div),i_{sc}(5A/div, 5ms/div)

4. Conclusions

In this paper, a three phase AC-AC matrix converter for a grid-connected variable wind power system is developed. Basic illustration for power circuit and commutation are given. Finally, experiment results of basic converter operation are shown.

Acknowledgement

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