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SVPWM Control of AC/DC Busbar Bi-directional Converter in Hybrid Micro Grid

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Abstract: The capacity of balance bus power and energy bidirectional flow was required for converter in hybrid micro grid system. This study proposed the rapid space voltage vector pulse width modulation (SVPWM) technology for bi-directional converter and analyzed the algorithm feasibility scheme based on the topological structure of three-phase voltage rectifier. The rapid SVPWM algorithm and the converter models are established in the simulation software MATLAB/Simulink. Then the simulation research for the ac/dc busbar bi-directional converter of hybrid micro grid is processed with SVPWM algorithm. The theory analysis and simulation results indicated that this SVPWM bidirectional converter is feasibility and superiority in this field.

Key words: AC/DC hybrid micro grid, Bi-directional converter, rapid SVPWM

INTRODUCTION

The distributed generation system is be- coming an important development direction in many countries and regions (Lasseter, 2011). In allusion to the electric power requirement advancing and the energy sources environment problem looming larger, distributed generation is developing fleetly along with country economy development in china. It is an effective approach to make full use of the distributed generation by connecting the micro grid system and smart grid (Guerrero *et al*., 2013). However, the distributed renewable energy power generation intermittence and randomicity characteristics restrict its power generation capability and its running stabilization (Radwan and Mohamed, 2012). The micro grid can join the distributed generation, burthen, energy storage equipment together through advanced control system and form a controllable cell. It not only run with distribution power system connection grid. but also run without grid (Akbari *et al*., 2011; Ding *et al*., 2012). The micro grid connection may dig the distributed generation well and bring the remarkable value into the power supply department and user.

Ac/dc hybrid micro grid structure contains the both AC busbar and DC busbar, control mode and the method, the power electronic transform devices and so on (Liu *et al*., 2011; Dong *et al*., 2011). The ac/dc busbar bi-directional converter plays an important role in this kind of structure, which can coordinate the power distribution and control in the operation state of hybrid micro grid system (Mohamed *et al*., 2011).

SVPWM converter is an ideal method to content the needs for the AC system and DC system of hybrid micro grid between the ac bus and dc bus. The dynamic mathematical model is established of three-phase voltage source SVPWM converter based on the three-phase voltage source rectifier topological structure. The voltage space vector control method was applied to process the dynamic real-time simulation for the converter and its performance was analyzed. The simulation results validated that the rapid control strategy were viable and effective.

Structure of the AC/DC hybrid micro grid system: The hybrid micro grid structure is shown as Fig. 1. Micro grid is composed of alternating current system (AC) and direct current system (DC) system that connected by ac/dc busbar bi-directional converter (Majumder, 2013). DC system structure of hybrid micro grid is parallel connection structure, such as solar power and fuel cell connected to the dc system through the DC/DC booster circuit. DC energy storage battery paralleled on the dc bus by the bi-directional DC/DC. The wind power system connected the DC bus by the rectifier. DC load accessed the micro grid through a DC bus. AC system structure of hybrid micro grid is similar to dc system structure, energy storage, diesel generator and load in parallel to the ac bus. And hybrid micro grid connected the power grid via ac bus through feeder line (Loh *et al*., 2013; Lu *et al*., 2013).

Hybrid micro grid structure support four operation modes: (1) ac and dc system is grid-connected operation mode, PCC1 and PCC2 switches are closed at this time; (2) ac system grid-connected operation, dc system islanded operation, PCC1 switch is closed, the PCC2 switch is disconnected; (3) ac and dc system is paralleling island operation mode, PCC1 switch is disconnected, the PCC2

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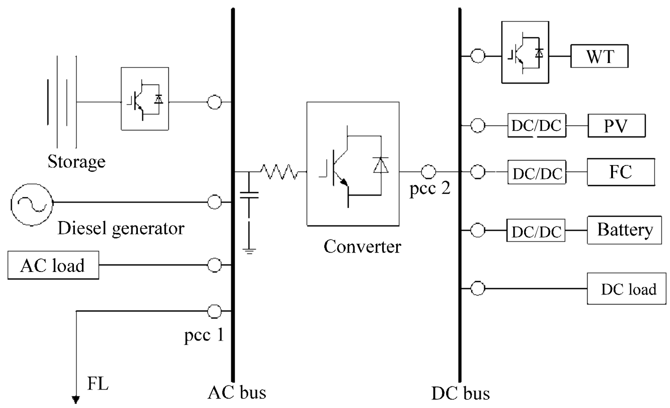

Fig. 1: Ac/dc hybrid micro grid system structure

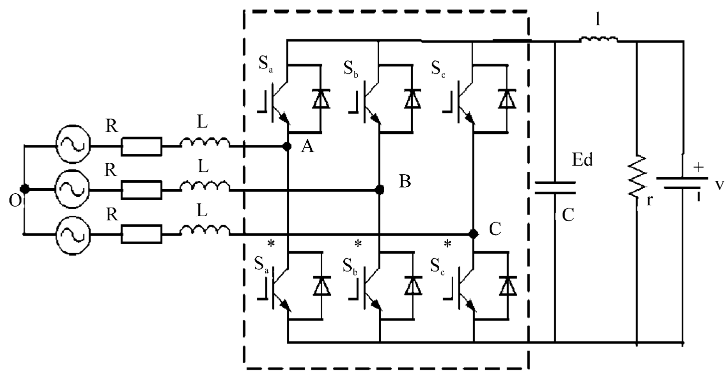

Fig. 2: Ac/dc busbar bidirectional converter structure

switch is closed; (4) ac and dc is splitting islanded operation mode, all the PCC1 and PCC2 switch are disconnected.

The energy management, control and operation management of hybrid micro grid is much more complex and technology is higher than ac and dc micro grids. Ac/dc hybrid micro grid bus bidirectional converter control technology is also demanded the characters of energy real-time bi-directional transmission and balance the bus power compared with the conventional converter. Therefore, the bidirectional converter of reasonable control is the important part to realizing the energy management and reasonable distribution in the hybrid micro grid.

MODEL OF CONVERTER AND SVPWM CONTROL STRATEGY

Ac/dc busbar bi-directional converter structure is shown in Fig. 2. The voltage space vector is defined as:

$$u_{ref} = u_{AO} + u_{BO}e^{-i2\pi/3} + u_{CO}e^{i2\pi/3} \quad (1)$$

The switching function of three-phase bridge is expressed as $s_k(k = a, b, c)$. $s_{k=1}$ represented up bridge arm breakover and down bridge arm turn off, $s_{k=0}$ represented down bridge arm breakover and up bridge arm turn off accordingly.

Ac side voltage can express in complex plane of a space voltage vector when the three-phase voltage source converter for different switch combination. SVPWM convertor has eight kinds of switch combination in normal working times. The eight vectors called the basic space voltage vector and the space is divided into six sectors, shown as in Fig. 3.

The first sector synthesized voltage u_{ref} is decomposed into basic space voltage vector at α/βcoordinate system, shown as in Fig. 4. In Fig. 4, u_{ref} is composed of the basic space voltage vector V_1 and V_2.In a complete cycle T_{pwm}, V_1 action time is T_1 and V_2 action time is T_2. The u_{ref} expression is described as:

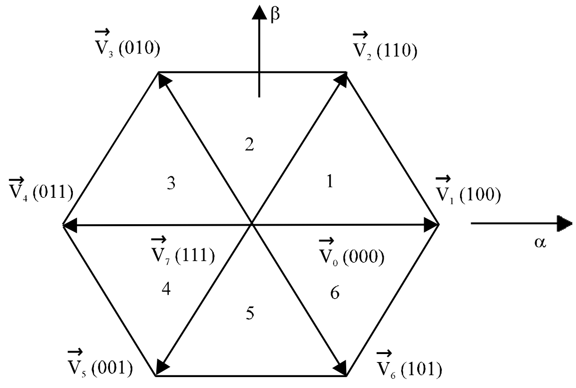

Fig. 3: Voltage vector and sector spatial distribution

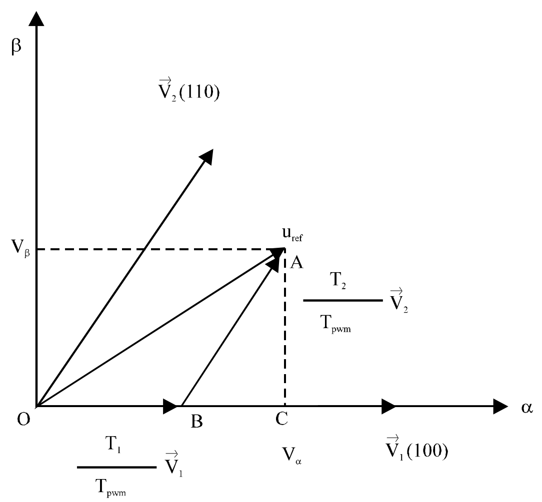

Fig. 4: Voltage vector composite diagram

$$\begin{aligned} u_{ref} &= u_{A0} + u_{B0}e^{-i2\pi/3} + u_{C0}e^{i2\pi/3} \\ &= (u_{A0} - 1/2u_{B0} - 1/2u_{C0}) + \sqrt{3}/2(u_{C0} - u_{B0})i \end{aligned} \quad (2)$$

Three-phase voltage relationship in the first sector can be described as:

$$\begin{cases} u_{AO} - \frac{1}{2}u_{BO} - \frac{1}{2}u_{CO} > 0 \\ u_{CO} - u_{BO} > 0 \\ \frac{1}{2}(u_{CO} - u_{BO}) < u_{AO} - \frac{1}{2}u_{BO} - \frac{1}{2}u_{CO} \end{cases} \quad (3)$$

where the equation passed series of mathematical resolving, can be considered as expressed in:

$$\begin{cases} u_{AB} > 0 \\ u_{BC} < 0 \\ u_{CA} < 0 \end{cases} \quad (4)$$

Table 1: Basic space voltage vector sector judgment condition and action time

Sector	Judgment condition u_{AB}	u_{BC}	u_{CA}	Corresponding basic space voltage vector and action time
1	>0	<0	<0	V_1×t (A, C)+V_2×t (C, B)
2	>0	<0	>0	V_3×t (C, A)+V_2×t (A, B)
3	<0	<0	>0	V_3×t (C, B)+V_4×t (B, A)
4	<0	>0	>0	V_5×t (B, C)+V_4×t (C, A)
5	<0	>0	<0	V_5×t (B, A)+V_6×t (A, C)
6	>0	>0	<0	V_1×t (A, B)+V_6×t (B, C)

The relationship of basic vector function time and the voltage can be obtained in the RTΔA BC, as shown in:

$$\begin{cases} |AB| = |V_2T_2/T_{PWM}| = E_dT_2/T_{PWM} = |AC|/\sin(\pi/3) \\ = 2|V_\beta|/\sqrt{3} = u_{CB} \\ |BC| = |AB|/\cos(\pi/3) = \frac{1}{2}u_{CB} \\ |OB| = |V_1T_1/T_{PWM}| = E_dT_1/T_{PWM} = |OC| - |BC| \\ = (u_{AO} - \frac{1}{2}u_{BO} - \frac{1}{2}u_{CO}) - \frac{1}{2}u_{CB} = u_{AC} \end{cases} \quad (5)$$

$$T_1 = T_{PWM}u_{AC}/E_d; T_2 = T_{PWM}u_{CB}/E_d \quad (6)$$

The other sectors judgment condition and basic space voltage vector function time was inferred similarly. As shown in Table 1.

STUDY SYSTEM AND SIMULATION RESULTS

Simulation parameter: In the example, the rated output power for the convertor P = 2 kW. System phase voltage value is 110 V, 50 Hz. Filtering inductance L = 2 mH. Dc side capacitor C = 220 μF. Given dc side voltage E = 300 V. Power supply equivalent resistance value R = 0.1 Ω. Load resistance R_L = 50 Ω.

Simulation result: Figure 5 is sector judgment waveform. The sector No. of synthesized voltage is judged according to the Table 1. The purpose is the reference voltage vector expression by the corresponding basic space voltage vector and action times. Figure 6 is the A phase bridge arm switching function waveform. The standard saddle waveform verified that the rapid SVPWM is validity. Figure 7 shows the results of reactive current component change from 0 to 20 A at 0.1 sec. In Fig. 7a, the A phase voltage u_a and current i_a waveform are shown of ac side in ac/dc busbar bi-directional converter. The converter from unit power factor converter have become a perceptual reactive power, realizes the power factor adjustment. In Fig. 7b, the ac side input active P and reactive power Q are shown, reactive power Q change with given reactive current

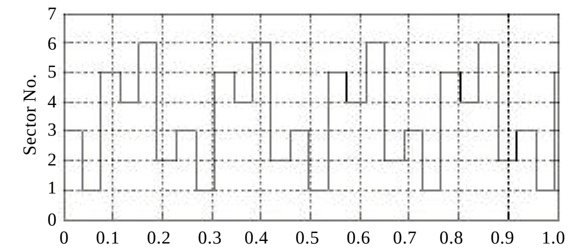

Fig. 5: Sector No. waveform

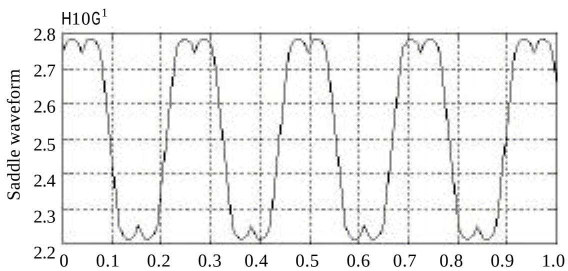

Fig. 6: A phase bridge arm switching function waveform

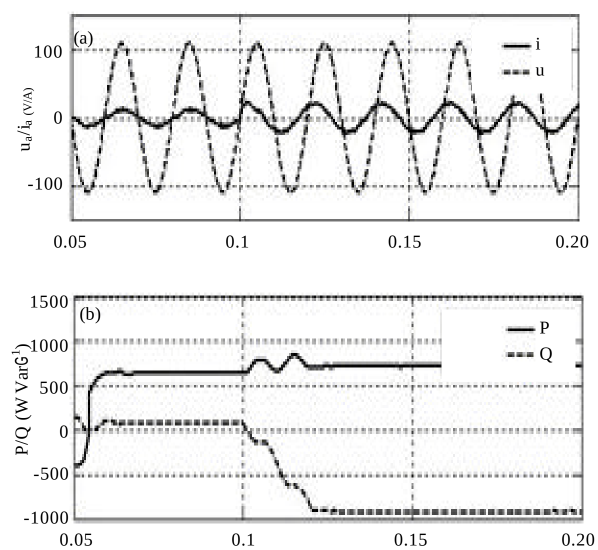

Fig. 7(a-b): Simulation waveforms of reactive current change (a) A phase voltage u_a and current i_a waveform and (b) Active power P and reactive power Q waveform

value, active power P remain unchanged after the short fluctuation, realizes the independent control of active and reactive power.

Figure 8 shows the results of dc voltage source changed from 0 to 500 V with counter electromotive force

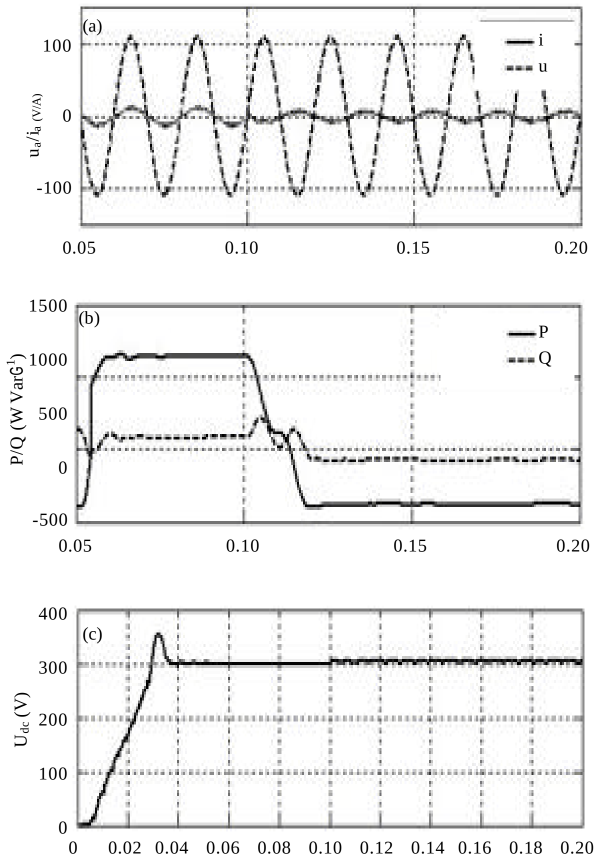

Fig. 8(a-c): Simulation waveforms of load change (a) A phase voltage u_a and current i_a waveform, (b) Active power P and reactive power Q waveform and (c) Dc side voltage waveform

load change at 0.1 sec. Figure 8a shows the A phase voltage u_a and current i_a waveform of ac side in ac/dc busbar bi-directional converter, u_a and i_a have the same phase before 0.1 sec, then changed the contrary phase along with the dc voltage source changed. That is to say the converter operates unit power factor inverter from unit power factor rectifier. The result indicated that energy bidirectional flow feature is realized for this SVPWM bi-directional converter in hybrid micro grid. In Fig. 8b, the ac side input active P and reactive power Q are shown, reactive power Q is zero value, active power P become negative value, that is to say converter change operation state from the absorption active power to the issue active power. This result demonstrated SVPWM bi-directional converter can good achieve the energy transmission between ac bus and dc bus in the hybrid micro grid. Figure 8c shows the dc side voltage of converter, the figure shows dc voltage U_{dc} is remained unchanged after the short fluctuation of SVPWM bi-directional converter. The result indicated this control strategy can balance bus power in dc side of bidirectional convertor when the load changed.

CONCLUSION

This study make the AC/DC busbar bidirectional convertor apply to hybrid micro grid based on rapid voltage space vector pulse width modulation technology. The theoretical analysis and simulation research validate the converter low harmonic, high power factor, fast dynamic response and energy bidirectional flow features. This control let the AC/DC busbar bidirectional convertor of hybrid micro grid system more conducive to realize the real time control.

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