Sensorless measurement of the DC link capacitor current of three-phase inverter

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3상 인버터의 DC 링크 커패시터 전류의 센서리스 측정

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ABSTRACT

A general method to measure the inverter DC bus capacitor current is described. It is an indirect estimated method. By measuring the input and out voltage and current can calculate DC bus capacitor current. This paper will develope the theory that describes the indirect method. It will discuss and verify the feasibility of this approach through the use of the PSIM. Using SPWM control method will be simulated and compared.

1. INTRODUCTION

Now the DC bus capacitor has been thought of as a component that sets the service life of an inverter. To increase capacitor life and to verify the DC bus capacitor sizing, it must start research. Many papers have been written about understanding and improving the life of the aluminum electrolytic capacitor used in inverter applications[1 3]. This paper will describe an indirect method to measure the DC bus capacitor current of inverter[4]. All measurements are made external to the drive. It employs common available test equipment. This paper use the PSIM for simulation. In the three phase inverter, it will get simulation result with SPWM controller. The following describes the specific methods and simulation.

2. THE PROPOSED METHOD

Fig. 1 shows an three phase inverter circuit. It add a capacitor in the side of the input. By the following method will measure this DC bus capacitor current indirectly.

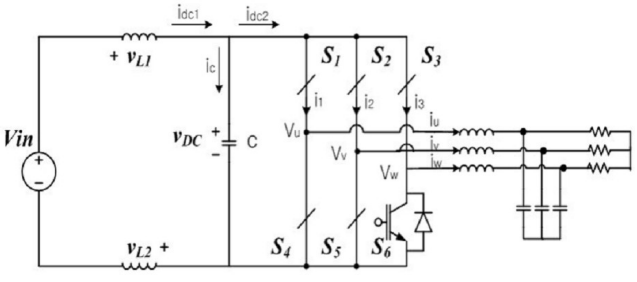

Fig.1. Three phase inverter

From Fig. 1, the DC bus capacitor current can be represented as

$$ic = i_{dc1} - i_{dc2} \tag{1}$$

where, ic is the DC bus capacitor current; i_{dc1} is the DC choke current; i_{dc2} is the inverter side DC link current.

The current of the i_1, i_2 and i_3 can be derived from the load side voltage directly through equation (2)

$$i_k = i_x * \frac{V_x - V_n}{V_p - V_n} = \frac{i_x}{V_{dc}}(V_x - V_n) \tag{2}$$

where, V_{dc} is the DC bus capacitor voltage ; x∈(u,v,w) is one of the output phase; Vp and Vn are the positive and negative DC bus voltage; i_k is one of the output phase current.

According to KCL theory, we can get the following equation(3)

$$i_{dc2} = i_1 + i_2 + i_3 \tag{3}$$

Through equation (2) and (3), we can know

$$\begin{aligned} i_{dc2} &= i_1 + i_2 + i_3 \\ &= \frac{[(V_u - V_n)i_u + (V_v - V_n)i_v + (V_w - V_n)i_w]}{V_{dc}} \\ &= \frac{[(V_u - V_n)i_u + (V_v - V_n)(-i_u - i_w) + (V_w - V_n)i_w]}{V_{dc}} \\ &= \frac{[(V_u - V_v)i_u + (V_w - V_v)i_w]}{V_{dc}} \end{aligned} \tag{4}$$

Combining equation (4) and (1), it can be found that

$$i_c = i_{dc1} - \frac{(V_u - V_v)i_u}{V_{dc}} - \frac{(V_w - V_v)i_w}{V_{dc}} \tag{5}$$

According to equation (5), we can estimate the DC bus capacitor current. The DC choke current, inverter side line to line output voltage and current, these can be measured through the appropriate equipments.

3. SIMULATION AND DISCUSSION

We uses the PSIM to simulate and discuss the correctness of the equation (5). The parameters used are:

1) input voltage: Vin=100[V]
2) input inductance and resistance:
$L_1 = L_2 = 1[mH], r = 0.2[\Omega]$
3) input capacitor : $C = 1[\mu F]$
4) output load : $R = 20[\Omega]$

5) output capacitor : $C1 = C2 = C3 = 10[\mu F]$
6) output inductor : $L = 10[mH]$
7) switching frequency : $F_{sw} = 5[kHz]$
8) modulation(m) : m=0.8

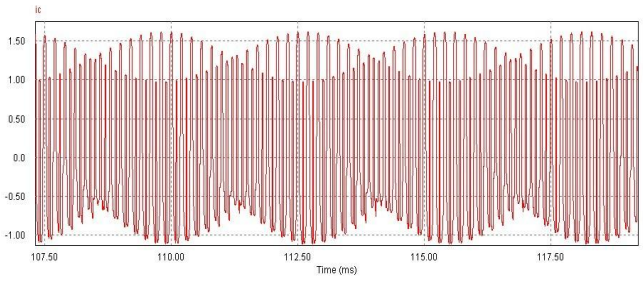

Fig. 2. The estimated DC bus capacitor current waveform

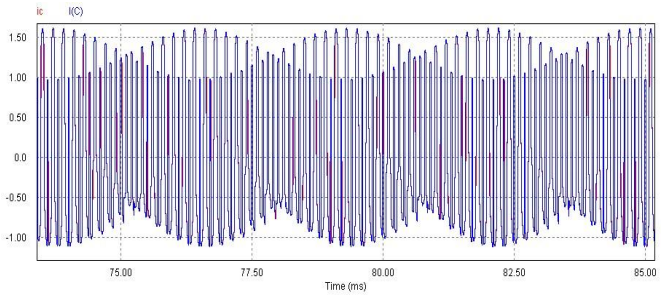

Fig. 3. The actual DC bus capacitor current waveform

Through the comparison of the estimated and actual, we can see the two kinds of waveform relationship. From figure 2 and 3, it can be seen that the error between the direct and indirect method equals to zero. The DC capacitor current obtain from direct and indirect method.

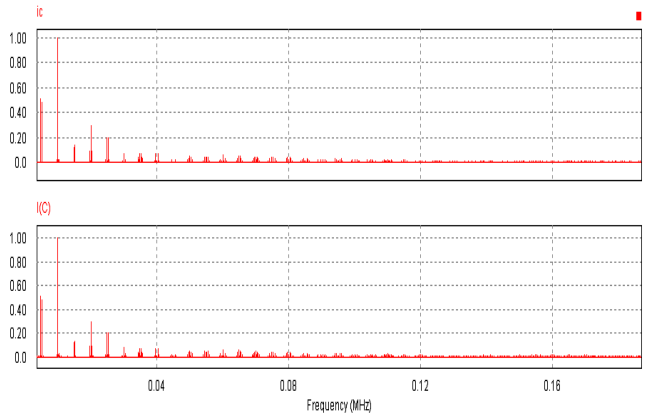

Fig. 4. DC bus capacitor current in the frequency domain.

Fig. 4. shows the FFT spectrum plots with directed and indirect method. The spectral components of the current occur at the same value in frequency compared to measured.

Fig. 5 shows the load side output current (Iu, Iw is the value of the equation). The load side output voltage(V_{P1},V_{P2},V_{P3}) is 40V.

According to equation, we can get

$$V_{out} = \frac{1}{2} * Vin * m = \frac{1}{2} * 100V * 0.8 = 40V$$

The output waveform also verified the correctness of the simulation. Through simulation, it can be concluded that indirect current method can also accurately measure the DC link capacitor current.

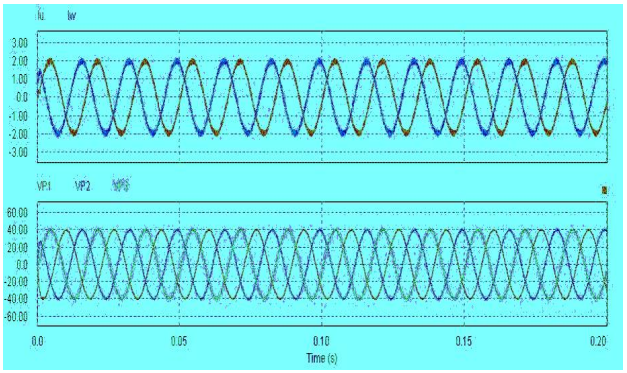

Fig. 5. The load side output current and voltage

4. CONCLUSIONS

The simulation result shows that the estimated DC bus capacitor current is consistent with the actual capacitor current. Measuring DC bus capacitor current can be a difficult task if the bus capacitor is embedded in the drive and difficult to reach. In order to tackle such a problem, we can the method of this paper. Because all measurements are made external to the drive in this method. After we have mastered this method, this method works for inverters connected to the AC mains or in a common DC bus configuration. It can try to research deeply.

호남광역권 광역경제권 선도사업의 "3 Level 기법을 이용한 3MW 이상급 풍력발전기용 전력변환기 개발" 과제의 지원으로 연구되었음

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