Capacitance Estimation of DC-Link Capacitor Considering Temperature Effect

Xingsi Pu*, Kyung-Hyun Kim*, Dong-Choon Lee*, Kyo-Beom Lee** , Jang-Mok Kim***

Dept. of Electrical Eng., *Yeungnam Univ., **Ajou Univ., *** Pusan National Univ.

Abstract

This paper proposes a correction method of capacitance estimation considering the temperature effect for the DC-link capacitor banks in three-phase AC/DC PWM converters. In this work, a sensing circuit using a temperature sensor is designed for measuring the operating temperature. Capacitance value is corrected considering the measured temperature. This method has been implemented in experiment.

1. Introduction

Three-phase AC/DC/AC PWM converters have matured in industrial applications widely. The aluminum electrolytic capacitor banks are usually used for these types of converters as an energy buffer. The electrolytic capacitor is the weakest device for a power converter. By aging effect, the capacitance of electrolytic capacitor is decreased, where it should be noted that the capacitance is sensitive to the operating temperature [1]. As operating temperature is increased, the capacitance is normally increased. The estimated capacitance needs to be corrected at other operating temperatures.

Fig. 1 shows a circuit of the three-phase AC/DC/AC PWM converter and the control block diagram of the front-end converter including the capacitance estimation [2] and temperature sensing algorithm. By considering temperature effect, the estimated capacitance gives a reliable judgment to indentify the condition of the capacitor.

2. Effect of temperature on capacitance

A data sheet [3] of the capacitor is provided to support our work. Capacitance increases as temperature increases and decreases as frequency increases as shown in Fig. 2(a). For this work, the values of capacitance at frequency 30Hz are important for investigation. Therefore, Fig. 2 (b) is derived from Fig. 2(a), taking the data at frequency 30Hz. A regulated AC current with a frequency (30Hz) is injected into the input side of the AC/DC PWM converter [4].

In order to sense the operating temperature, a cheap thermal resistor (thermister) [5] is used, which varies with temperature. Fig. 2(b) shows the capacitance variation over operating temperature from -40°C to 85°C. Therefore, an operating temperature range of the thermister is also selected from -40°C to 120°C. The sensing circuit is designed as shown in Fig. 3, based on the characteristic of the thermister. The surface temperature is considered similar to the internal operating temperature. As the operating temperature increases, the resistance of the thermister decreases. As thermister resistance decreases, the voltage across the thermister decreases.

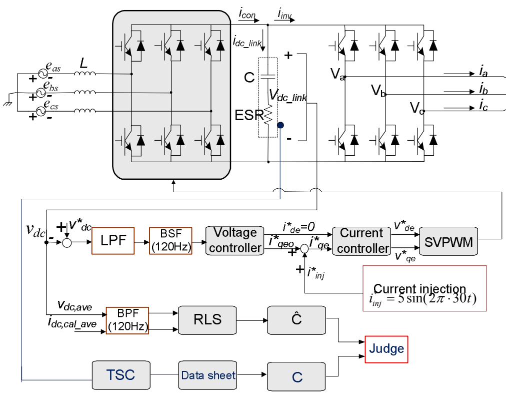

Fig. 1 Control block diagram for estimating capacitance and ESR for three-phase AC/DC/AC PWM converters.

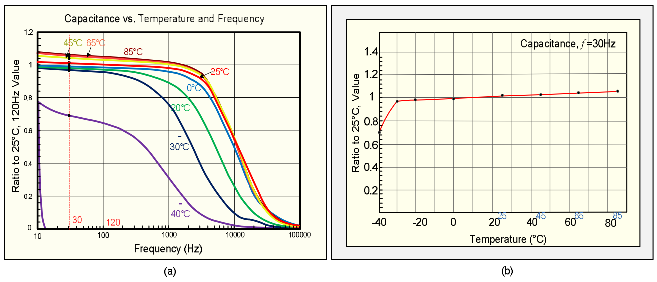

Fig. 2 (a) Capacitance vs. frequency with temperature as a parameter (b) Capacitance vs. temperature (at 30Hz)

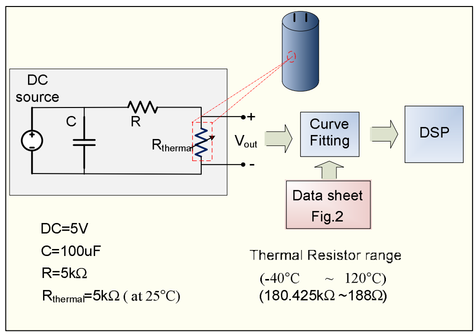

Fig. 3 Temperature sensing circuit

3. The temperature sensing approach

3.1 Temperature sensing

The temperature sensing principle is shown in Fig. 3. By using curve-fitting tool in Matlab, the relationship between temperature and resistance [3], the relationship between resistance and output voltage are shown in Fig. 4(a) and (b), respectively. Combining Fig. 2(b) with Fig. 4(a) and (b), the output voltage and capacitance can be found directly as shown in Fig. 4(c).

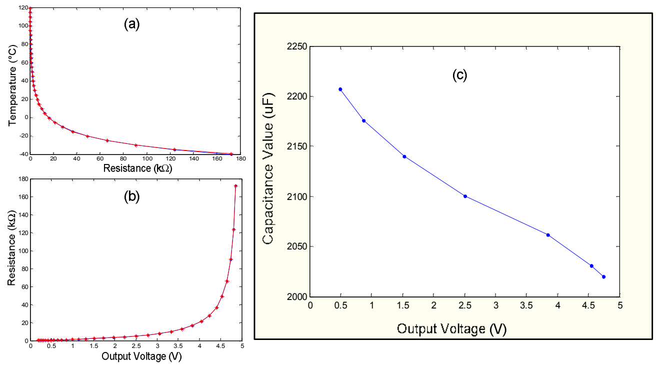

Fig. 4(a) Relationship between temperature and resistance
(b) Relationship between resistance and output voltage
(c) Relationship between output voltage and capacitance

3.2 Computation of capacitance

For the purpose of capacitance estimation, the average i_{dc,cal_ave} values of DC-link current need to be known. The capacitance of the DC-link capacitor, C, can be calculated using the average value of current and voltage [2].

The second-order band-pass filters are applied to extract the DC-link current and voltage ripple components at the injected frequency. Then, the recursive least squares is used for updating the parameter C .

4. Experimental results

To verify the effectiveness of the proposed scheme, the experiment has been carried out using the setup shown in [2].

Fig. 5 and 6 show the performances of voltage and current controllers, respectively. The currents flowing into DC-link are shown in Fig. 7. Fig. 7(b) shows the zoom in of (a). In Fig. 8, the experimental curve-fitting by temperature sensor confirms that the temperature effect can be sensed successfully. Its range is from +10°C to +80°C less than theoretical temperature range in Fig. 4. Fig. 9 shows the capacitance estimation performance considering temperature effect. The thermister is fixed on the surface of the capacitor. The sensed temperature is translated into the corresponding capacitance value by using datasheet in Fig. 8. In Fig. 8, the referred capacitance 2,100 [uF] of a healthy capacitor is obtained at 25.3°C (at 2.49V). In Fig. 9, the estimated value is compared with the capacitance 2,100 [uF] corresponding to at 25.3°C. The estimated value follows its referred one, and that means the condition of capacitor is healthy since the reduction percentage is less than 20% in Fig. 9 [2].

5. Conclusions

In this paper, the capacitance estimation considering the operating temperature of DC-link capacitors has been proposed. Through a cost-effective sensing circuit using a thermister, temperature effect can be involved for correction of capacitance estimation successfully. The DC-link electrolytic capacitor can be diagnosed against its deterioration more accurately.

Acknowledgment

This work has been supported by KESRI (20091020300380-11-2-100), which is funded by MKE (Ministry of Knowledge Economy).

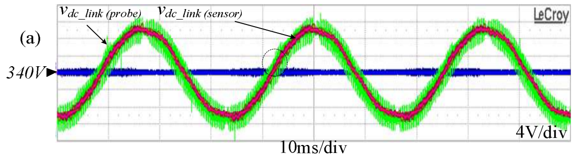

Fig. 5 Performances of DC-link voltage (by probe and sensor)

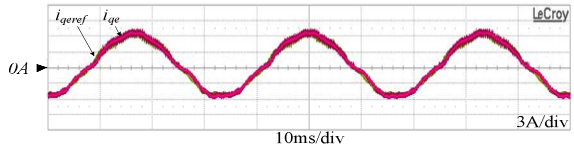

Fig. 6 Performances of current controller

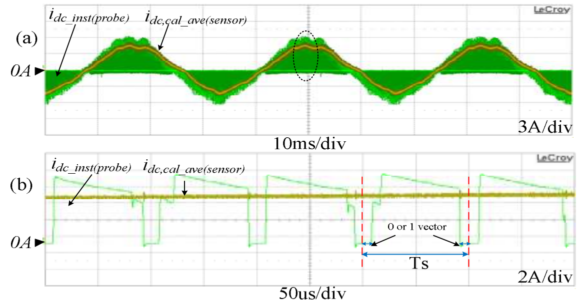

Fig.7 (a) Instantaneous DC-link current, and its average value (b) zoom in on (a).

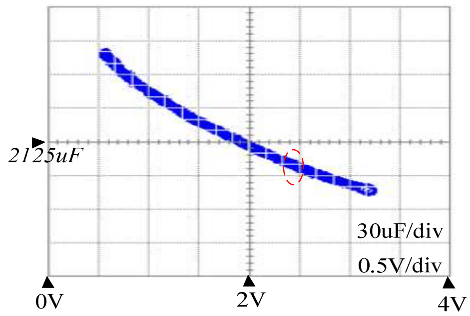

Fig. 8 Experimental curve fitting by temperature sensor

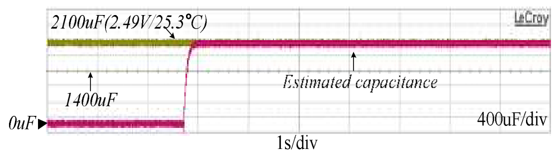

Fig.9 Estimation performance considering temperature effect

Reference

[1] S.K. Maddula and J.C. Balda, “Lifetime of electrolytic capacitor in regenerative induction motor drives”, in *proceedings of IEEE PESC*, pp153-159, 2005.

[2] X.-S. Pu, D.-C. Lee, K.-B. Lee, and J.-M. Kim, “Estimation scheme of capacitance and ESR in DC-link capacitors”, in *proceedings of KIEE EMECS Spring Conf.*, pp.161-163, 2010.

[3] Cornell Dubilier, *Application guide, aluminum electrolytic capacitors,* www.cde.com.

[4] D.-C. Lee, K.-J. Lee, J.-K. Seok, and J.-W. Choi, “Online capacitance estimation of DC-link electrolytic capacitors for three-phase AC/DC/AC PWM converters using recursive least squares method”, *IEE Proc. Electric Power Applicat.*, Vol. 152, No. 6, pp. 1503-1508, 2005, November.

[5] Samkyung Ceramics, *NTC_502F397F, Datasheet*, www.skceramic.com