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Simple Model Based Dead Time Compensation Using Fast Current Measurement

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Abstract

Nowadays the increasing utilization of alternative energy sources demand three phase power converters capable of delivering high quality energy to the low voltage grid. Good dead time compensation hardware and software are essential to keep low order harmonics at acceptable levels even at light load conditions, at acceptable costs. Low current waveforms with multiple zero crossings within a switching period are still problematic with today's technology. Such operating conditions often happen in PWM inverters and in variable frequency drives at or below 10% load. This paper describes a new method which uses a model for calculating the voltage error caused by dead time for each phase leg. The method is completely software based, but requires fast current measurement. A model splits each half period of the triangular carrier to time segments where the slopes of the currents in all phases, and the output voltage of all semiconductor phase legs are constant. It determines the duration of each of the time segments, and integrates the volt-seconds for a half period of the triangular carrier. The model is capable of handling discontinuous conduction as well. The resulting error voltage can be used to calculate a new, compensated duty factor which can be applied to the PWM modulator. The described algorithm was tested via computer simulation. A comparison was made with other, previous methods using the same inverter model.

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Keywords: PWM; inverter; dead time; linearization; model; volt seconds;

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1. Introduction

In symmetric three phase PWM controlled voltage sourced inverters, as seen on Fig 1., the switch controller always drives both controllable switches in a phase leg to the off state for a small time interval

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during switch-over to avoid shoot-through. This time is always more than what is needed for the switches to turn off for safety reasons. The remaining time is called effective dead time. It is marked with t_d in this paper.

During t_d only the anti-parallel diodes can conduct the output current. This will cause an error voltage on the output which needs to be compensated for, as recognized and described in [1]. If the dead time is long enough, discontinuous conduction may also appear. The presence of effective dead time thus introduces output waveform distortion and harmonic content in the output current of inverters. The effects become more severe at increased switching frequencies.

1.1. Existing compensation methods

The main circuit of a general three phase inverter with inductive load can be seen on Fig. 1. Most classical software based methods, such as the ones described in [1] [2] and [3] intervene based on the signum(I) function and thus are only capable of compensating for large positive or negative current waveforms. From this point of view, these methods share the same limitations, even if there are huge differences in the number of sensors used and in the methods of the calculation of error voltage or volt-seconds lost due to dead time.

Looking at the circuit diagram on Fig. 1. it can also be understood that for continuous current waveforms having zero crossings, most of the volt-seconds lost during one switch - over (which happens during positive current) are gained back during the next switch-over (during negative output current) within the same switching period. This state of operation is taken in to account in some compensation methods, like in [4].

There are methods which try to solve the problem by using extra detection hardware for each switching element as described in [5] and [6]. These are cheap compared to fast current measurement devices and fast A/D converters, but can detect the momentary current direction when a switch-over is initiated. This detection might be problematic for current waveforms having multiple zero crossings within one switching period.

1.2. Low current problems

Handling continuous current waveforms with zero crossings is not always possible using conventional methods; this already requires an accurate measurement or at least calculation of the inverter currents. The threshold between large positive or negative currents and nearly zero currents is defined by the current ripple.

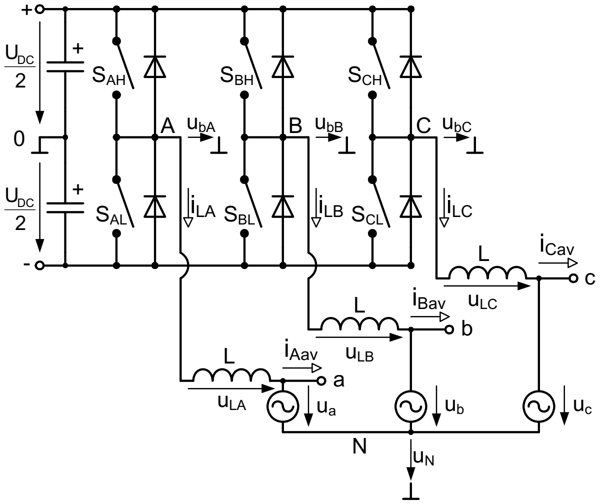

Fig.1. Main circuit of a general three phase inverter.