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Igbt Modular Structures of Power Inverters with Two and Three Levels of the Output Tensions: Effects of the Frequencies of the First Harmonics and the Switching on the Temperature

KEYWORDS: IGBT inverters, temperature effects, first harmonics, two (2L) and three (3L) levels.

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ABSTRACT The communication reports a study on the temperature effects of the frequencies of the first harmonics as well as the switching in case of IGBT inverters under conditions of equal output powers. Three-phase IGBT inverters with two (2L) and three (3L) levels of the power outputs have been investigated. The inventers with three levels (3L) have been investigated in case with passive (3L-NPC) and active (A-NPC) restrictions with respects to the neutral. Some advantages of the 3L modules at high frequencies of commutations have been discussed.

1. Introduction

The electronic inverter is based on transistor elements under a continuous commutation. This method is very effective with low energy losses. The transition from the "off" state to "on" state passes includes the current switched, the voltage handled, and the switching speed, characterized by the rise and fall times. This means that collector current passes through the highlyresistant base-collector zone that is related to high heat dissipation into the structure.

The electric circuit model of the heat transfer process of the IGBT module shown in Fig. 1 indicates that parasite losses of the resistances P_{RCC+EE} cannot be considered of the losses in the diodes and the IGBT microchips. Precisely, they are dissipated through the module and its base [1].

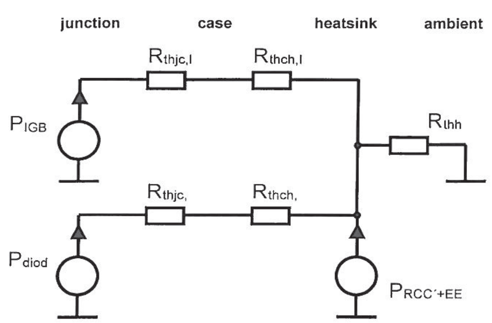


Fig.1 Thermal model of IBGT microchip.

The minimization of the local thermal loads of the crystal requires suitable structural design during the transistor formations, the internal architectures of the microchips and the configurations of the modules.

This work focuses the attention on thermal loads of the microchip crystal as a consequence of the first harmonic **F_O[Hz]** and the switching frequency **F_{sw}[kHz].** The principle module structures of inverters (2L and 3L) under equal working conditions are at issue.

2. Module structures of IGBT inverters

The common inverter with two levels of the output tension (see Fig.2) is based on low number of structural elements and easily controlled, that explains its large number application. The principle of its operation is based on pulse-width modulation (PWM) modulation of the output pulses along the time axis, keeping constant amplitude.

Successful solutions with respect to the energy efficiency are the inverters with more than two output levels. The inerter with three levels (3l), for instance, is the first stage of development in this direction. As a topological solution the version based on the neutral point clamping (NPC) dominates [2]. This approach has two modifications: 3L structures with passive neutral point clamping (3L-NPC) and 3L structures with active poit clamping (A-NPC)- see Fig. 2.

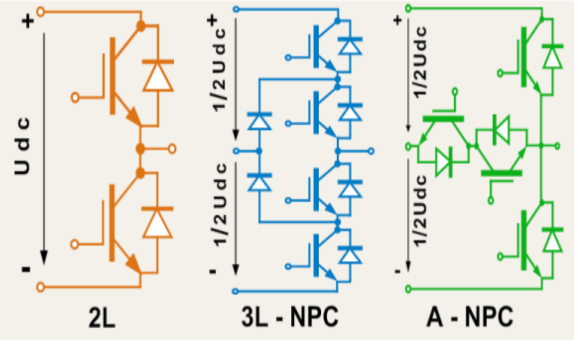


Fig.2 Structures of IGBT modules

Many transistor elements in the inverters with 3 levels allow better temperature fields and dissipations in the bulk of the modules. The fact that the commutation of an active element is time-dependent under the application of the only a half of the DC tension applied (½ **U_{DC}**) results in low power dissipation in the module body (**P_{SW}**). The distrubutions of the energy losses (**P_{con}**) for the three structures are discussed elsewhere [3] .

3. Thermal characteristics of IGBT module structures

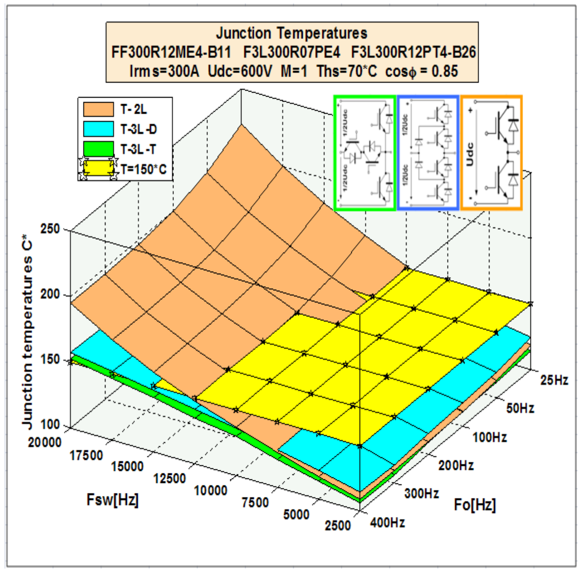
The simulations of the thernal characteristics refers to three-phase inverters with equal power ouputs, commercially supplied by Infineon Ttechnologies. The temperatures of the module structures were calculated by the IPOSIM code suplied the producer [4] . The studies were performed for operating modes: inverter and rectifier [5] . In both cases the effects of the main frequency **F_O[Hz]** and the frequency of switching in inveerter mode **F_{sw}[kHz]** are at issue.

The simulations used the IGBT module **FF300R12ME4_B11** as a device with two-levels of the output tension **U_{out}**.and **F3L300R07PE4** and **F3L300R12PT4_B26** as three-level inverters (with passive and active *Neutral Point Clamping*).

For the three inverter schemes the results have been obtain under a condition of eqaual heat dissipation (eqaul cooling conditions). The experimetal conditions for the ½ period are eqaul input parameters for all thre inveters studied, namely: nominal current **I_{rms} =300A** per phases, DC tension **U_{dc} =600V** , coefficient of modulation M=1 and temperature of the chip external surface **T_{hs} =70 ℃ ,** as well as **cosφ=0.85.** The graphical presenation of the temperature characteristics summarised in Tables 1 n

Tables 1

		FF300R12ME4_B11		2L	Temp.[C*]-1[phase]		
Fsw[Hz]	2500Hz	5000Hz	7500Hz	10000Hz	12500Hz	15000Hz	17500Hz	20000Hz
Fo=25Hz	118,2	128,3	139,4	151,7	165,4	181,2	200,3	223,8
Fo=50Hz	113,4	122,5	132,5	143,5	155,9	170,1	186,7	208,3
Fo=100Hz	111	119,6	129	139,3	151	164,5	180,1	200
Fo=200Hz	109,7	118,2	127,3	137,3	148,7	161,6	177	196,2
Fo=300Hz	109,3	117,8	126,9	136,8	148	161	175,9	195,2
Fo=400Hz	109,2	117,6	126,7	136,6	147,8	160,7	175,9	195,1
		F3L300R07PE4			3L-D	Temp.[C*]-1[phase]	
	2500Hz	5000Hz	7500Hz	10000Hz	12500Hz	15000Hz	17500Hz	20000Hz
Fo=25Hz	124,5	130,1	136	142,1	148,3	154,6	161	167,6
Fo=50Hz	119,4	125	130,3	135,6	141,5	147,1	152,8	158,9
Fo=100Hz	117,8	122,7	127,7	133,2	138,2	144	149,3	155,2
Fo=200Hz	116,4	123,2	128,2	133	138,5	143,3	149,3	154,8
Fo=300Hz	114	122,3	129,4	134,4	139,2	144,9	150,3	156,1
Fo=400Hz	114,8	122,1	128,9	136,3	141,3	147,1	152	157,2
		F3L300R12PT4_B26			3L-T	Temp.[C*]-1[phase]	
	2500Hz	5000Hz	7500Hz	10000Hz	12500Hz	15000Hz	17500Hz	20000Hz
Fo=25Hz	114,2	119,9	125,9	132,1	138,5	145,2	152,2	159,4
Fo=50Hz	111,9	117,6	123,2	129	135,3	141,5	148	154,9
Fo=100Hz	111,5	116,5	121,8	127,8	133,3	139,8	145,9	152,7
Fo=200Hz	109,3	117	122	127	132,9	138,4	145	151,4
Fo=300Hz	106,4	114,7	123	127,9	133,6	139,1	145,5	151,7
Fo=400Hz	106,6	114,1	121,1	130	134,8	141	146,8	152,4



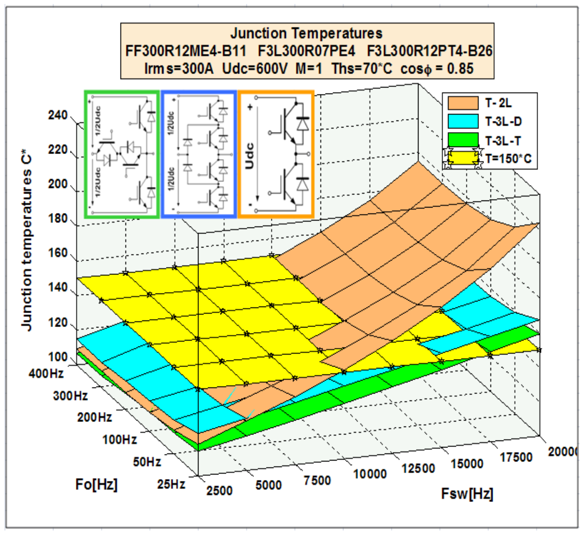


Fig.3 Temperature characteristics of the three module structures studied.

4. Conclusions

The inverters with 3 levels of the output tension in both modifications studied here have advantages with respect to the module temperature at high frequencies of PWM. Differences were observed at about 10 kHz frequencies of switching and beyond. For working frequencies below 100 Hz, the temperature of the modules with 2 levels of the output tension (**FF300R12ME4_B11**) progressively rises.

The advantages of the classical 2L inverter are mainly manifested in the rage of switching frequencies below **F_{sw}=10kHz.** The low number of structural elements and the uncomplicated control assure widespread as supplies for the elextric drives and low-level power consumption devices.

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