Practical and consumer aspects of transistor selection for combined MOSFET/IGBT legs in PWM inverters.

Angel Marinov [1], Vencislav Valchev[1]

Abstract **This paper considers some practical and consumer aspects of using the loss reducing topology of combined IGBT and MOSFET for power legs. The paper presents a study of possible selection of MOSFETs and IGBTs for realizing the combined topology, considering areas of power rating interception for the two types of transistors. Thus an optimal transistor selection can be realized. A simplified estimation of switching and conduction losses is derived based on a statistical number of MOSFETs and IGBTs, as well as price comparison between the MOSFET and IGBT combined leg and classical MOSFET or IGBT legs.**

Keywords – **IGBT, MOSFET, Loss reduction, Power electronics, Inverters**

I. INTRODUCTION

In many modern applications, such as motor drives and grid injecting inverters there is a need of high efficiency PWM inverters. In most of those cases the inverter should be able to provide an easy controllable output with wide range of regulation [2]. This means that resonant and soft switching techniques should be avoided due to the complicated control, thus restricting to the classic half or full bridge inverters. Conventional inverters however have decreased efficiency due to higher switching losses because of their hard switching nature. This paper presents a detailed study on an approach designed to reduce switching losses in conventional PWM inverters working under inductive load. The suggested technique uses a full bridge topology where instead of the symmetric transistor selection - either with only MOSFETs or IGBTs, a combination of both is applied. Figure 1 shows a single leg of the suggested topology. The leg can be used to build either single or three phase inverters, where depending on the control technique the total losses can be reduced. [1, 4]

The schematic shown on figure 1 uses a combination of IGBT and MOSFET, where the MOSFET is at the top and the IGBT is at the bottom, this could also be done in reverse, but it is imperative in order for the topology to work that the IGBT is used for conducting during the half wave and the MOSFET is used to modulate the wave. In this way when switching in high modulating frequency the tail current – appearing in pure IGBT topologies is avoided, because the MOSFET is taking on the modulation, thus reducing the turn-off losses. Meanwhile turn-on losses are reduced because the current stored in the inductor – I2 is conducted through the fast incorporated diodes of the IGBT, that have shorter reverse recovery compared with the parasitic body diodes of pure MOSFET topologies. (figure 2). [1, 4].

[1] Angel Marinov, Vencislav Valchev and Plamen Yankov are with Faculty of Electronics, Department of Electronics and Microelectronics, Technical University of Varna, Bulgaria .

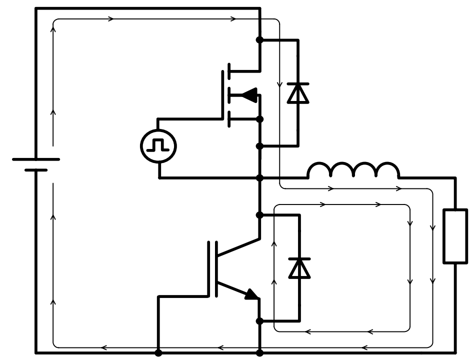

Fig. 1. Suggested MOSFET and IGBT combined Leg

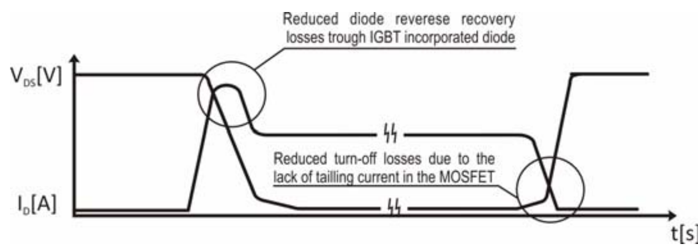

Fig. 2. Switching loss reduction.

The suggested topology was tested and proven. Simplified test results for the schematic from figure 1 are shown on figures 3,4,5 and 6. Figure 3 presents the turn-on current of the MOSFET (S1) in the case the tested leg was build using the MOSFET-IGBT combination. Compared to figure 4 where the leg was build only with MOSFETs it is clear that the turn-on losses will be higher due to the higher turn-on current.

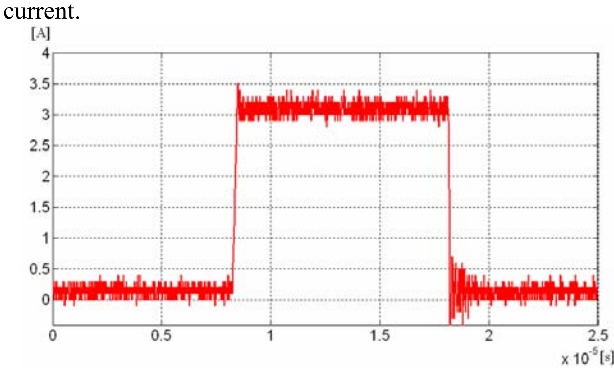

Fig. 3. Turn-on current of the proposed com-bined MOSFET-IGBT leg (less turn ON switching losses)

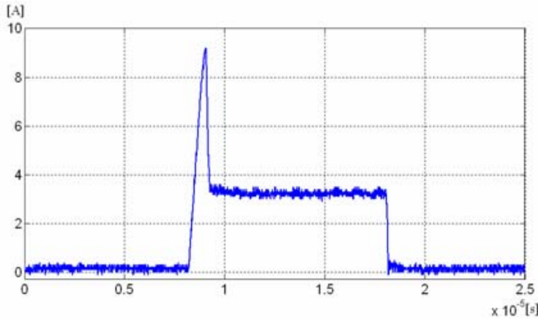

Fig. 4. Turn-on current trough a pure MOSFET leg.

Figure 5 presents the turn-off current of the of the same transistor – S1 where figure 5 is for the IGBT-MOSFET combination and figure 6 is for an IGBT only topology. It is clear that due to the lack of tail current in the turn-off the losses in the IGBT- MOSFET will be less compared to normal IGBT topology.

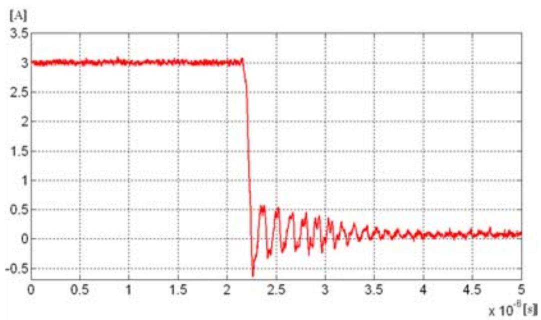

Fig. 5. Turn-off current of the proposed com-bined MOSFET-IGBT leg (lack of tailing current)

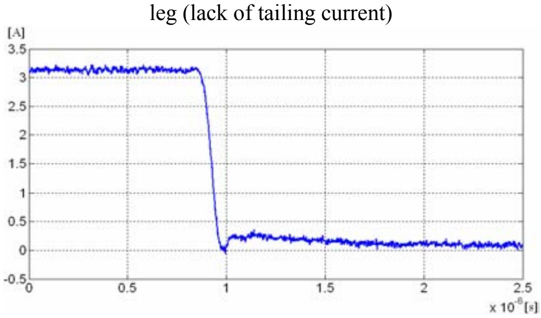

Fig. 6. Turn-off current trough a pure IGBT leg.

II. Statistical Study

The main aspect of this paper is to provide sufficient data and information on possibilities of building MOSFET/IGBT combined topology using easily reachable and common components. This means that the approach of selecting the transistor should involve inexpensive components with low losses. To determine when this is possible a study on a selected number of transistors was made. The transistor selection was made for both IGBTs and Power MOSFETs where the most common power rates were included. The number of the studied power MOSFETs is 174 and number of the studied IGBTs is 365. The parameters used in the study are maximum collector emitter voltage Uce(max), maximum continues collector current Ic, the on collector emitter voltage, and average price for single piece for the IGBT, as well as the equivalent parameters for the MOSFET.

III. Selection Based on the Power Rates

Figure 7 presents the studied selection of IGBTs and MOSFETs graphically sorted by maximum continues current and maximum blocking voltage. The figure clearly shows that the best mach when combing IGBTs and MOSFETs is located near the 600V when related to blocking voltage – and between 0 and 65A when concerning continues current. Appling those limits 184 different IGBTs and 90 different MOSFETs can be sorted out of the studied selection. This includes approximately 50% of all studied IGBTs and about 51% of the studied MOSFET.

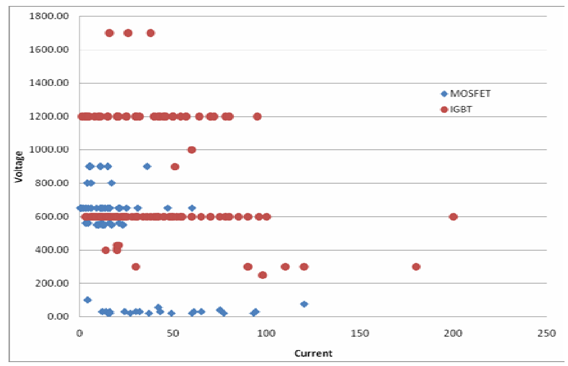

Fig. 7. Price relation for building IGBT, MOSFET and IGBT/MOSFET topologies.

IV. Selection Based on the Price Consideration

Figure 8 presents the price relation (comparison) of IGBTs, MOSFETs and IGBT/MOSFETs. The studied selection for this graph is reduced in order to form a best power rating mach for the combination. It can be seen from the graph (figure 8) that prices for MOSFETs have linear relation to the current and that IGBTs are less expensive and have a more curved relation. The IGBT/MOSFET combination stands in the middle. Thus, it is less expensive than the MOSFET topology but with the gained efficiency.

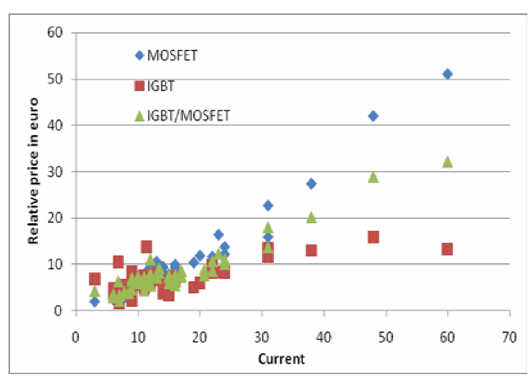

Fig. 8. MOSFET and IGBT availability in relation to power ratings.

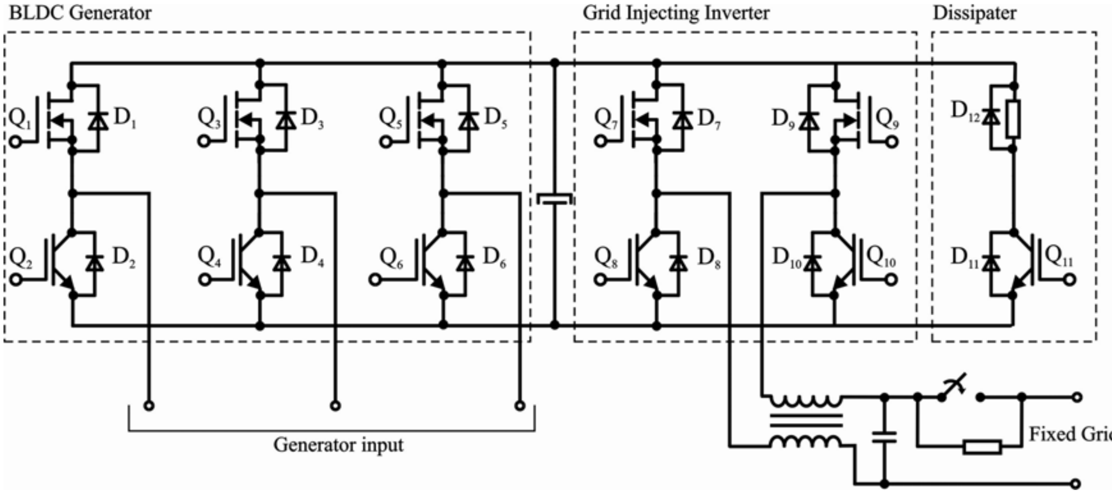

Fig. 9. IGBT – MOSFET topology for Combined Heat and Power system

V. APPLICATION OF THE IBGT-MOSFET TOPOLOGY

The purposed topology was successfully implemented in a system for Combined Heat and Power and was used as a three phase inverter for brushless DC motor/generator drive and as a single phase grid injector. (figure 9, the figure also includes the output filter of the grid injector and a dissipater for protection).

The transistors used for application were selected based on the presented study are shown in table 1.

TABLE I
TRANSISTOR SELECTION

IGBT		MOSFET	
IRGP4062D	Price:6,38€	STW26NM60	Price:8,94€
V_{CE}=600V, I_C=24A, V_{CE}=1,65V		V_{DS}=600V, I_D=19A, R_{DS}=0,135Ω	
IGBT switching characteristics		MOSFET switching characteristics	
$t_{d(on)}$=40ns	I_c=24A,	$t_{d(on)}$=35ns	I_D=13A,
t_r=24ns	V_{cc}=400V,	t_r=22ns	V_{DD}=300V,
$t_{d(off)}$=125ns	R_G=10Ω,	$t_{d(off)}$=14ns	R_G=4,7Ω,
t_f=39ns	T_j=175°C	t_f=20ns	T_j=150°C
IGBT incorporated diode switching characteristics		MOSFET incorporated diode switching characteristics	
t_{rr}=89ns	I_F=24A,	t_{rr}=560ns	I_F=26A,
Q_{rr}=4,3μC	T_j=175°C	Q_{rr}=9μC	T_j=150°C

VI. CONCLUSION

The carried out statistical study reveals the power range where MOSFETs and IGBTs the combination is most effective. Data for price estimation is provided for the combined components in relation to the normal IGBT and MOSFET topologies. It is proved that the MOSFET/IGBT topology is less expensive than the MOSFET technology and moreover, it is more efficient than both MOSFET and IGBT topologies.

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