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# Feasibility study of a Medium Voltage **DC/DC Converter adopting WBG** devices

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### **Research context and motivation**

· Research activity is based on the TransPod Project. The main Project topic is about the design of an innovative Ultra-high speed vacuum tube train. The TransPod vehicle (Pod) is built like an airline jet fuselage, containing rows of seats inside



- One of the partner of the project is IKOS. IKOS company
- leader of Railway engineering, with more than 900 engineering consultants working on projects around the world. The aim of the research is the design an high power density DC/DC Converter.
- The DC/DC converter will be designed in a collaboration between IKOS and the energy department of Politecnico di Torino. The goal is to use Wide band gap (WBG) devices in the design. **MOTIVATION AND CHALLENGES**



Commutation problem related to Medium Voltage (MV) using Silicon Carbide (SiC) transistor. Hard and soft switching comparison with WBG devices in MV range. The individuation of the parasitic elements and the resonant phenomena of High Frequency (HF) transformer.

Fig 1. - POD Vehicle and the on-board electrical power system distribution

### Addressed research questions/problems

- · New medium voltage SiC mosfet prototype are changing the concept of the Multilevel. New technologies are pushing in the direction to increase the break-down voltage of the single switch. Currently, SiC and GaN components are able to carry few current than Si devices
- The driver circuit of the high voltage SiC transistors.
- Evaluation of the parasitic element in a high frequency transformer in order to define the equivalent electric circuit.

### **Novel contributions**

- Use of a high voltage SiC MOSFET in a medium voltage converter. The integration and the packaging of the High voltage WBG chips is innovative too.
- · Use a new structure to develop a medium voltage DC/DC converter.



#### <u>Submitted and published works</u>

- Ruffo R., Cirimele V., Diana M., Khalilian M., La Ganga A., Guglielmi P., "Sensorless control of the charging process of a dynamic inductive power transfer system with an interleaved nine-phase boost converter", IEEE Transactions on Industrial Electronics, vol. 65, 2018, pp. 7630-7639
- La Ganga A., Cirimele V., Ruffo R., Guglielmi P., "Fast hardware protection for a series-series compensated inductive power transfer system for electric vehicles", Southern Power Electronics Conference (SPEC), Puerto Varas (Chile), 2017, pp. 1-6 La Ganga A. , Guglielmi P. , Armando E. , "Auxiliary circuit design for soft switching in medium voltage application using 1.7 kV
- La Garga A., Guglienin F., Annaho E., Auxing Circuit design for soil switching in medium voltage application damp in SiC MOSFET, International Telecomunications Energy Conference (INTELEC), Torino(Italy), 2018, pp. XX-XX Diana M., Colussi J., La Ganga A., Guglielmi P., 'An innovative direct cooling system for integrated electric drives", Workshops on Electrical Machines Design, Control and Diagnosis (WEMDCD), Athens (Greece), 2019 Crimele V. at al., 'The Fabric ICT platform for managing Wireless Dynamic Charging Road lanes", IEEE Transactions on Debinder Techengen;
- Vehicular Technology.





### Adopted methodologies

#### **PROTOTYPING STAGE**

- Mechanical and Electrical design of a 200 kW DC/DC converter using 1.7kV 300A SiC Mosfet.
- · Low level control managed by FPGA, high leve control managed by microcontroller









Fig 8. – Control board



Fig 9. – Gate Driver board and 1.7kV 300A SiC Mosfet inverter leg

lation up to 5kV DC HIGH FREQUENCY TRANSFORMER

The galvanic insulation in a medium voltage converter is mandatory in the most of case. The aim of the simulation is to identify the parameters for the equivalent electric circuit model of the high frequency transformer.



#### Future work

- Test the DC/DC Converter using HV SiC components.
- Define the equivalent electric circuit of the high frequency transformer using the measurement on a real component.
- Test and evaluate the control strategy for the DC/DC converter.

#### List of attended classes

2017/2018

- 02LWHRV Comunication (15/02/18, 5h, SS) 01PJMRV Etica informatica (14/03/18, 20h, SS) 08IXTRV (15/02/18, 5h, SS) - Project management 01RISRV - Public speaking (15/02/18, 5h, SS) 02RHORV – The new Internet Society (13/03/18, 5h, SS) 01SGRRV - Magnetic materials for electrical energy (23/11/17, 20h, HS) 01RGBRV – Optimization methods for engineering problems (13/06/18, 30h, HS) 01SFURV - Programmazione scientifica avanzata in matlab (13/04/18, 20h, HS) **EXTERNAL TRAINING ACTIVITIES** Summer Course on Power Electronics and Applications. (06/07/18, 30h, Rome) European PhD School Power Electronics, Electrical Machines, Energy Control and Power Systems. (21/05/18, 30h, Gaeta) 2018 / 2019 • 01ROERV - Sensorless control of electric machines (21/01/19, 25h, HS) **EXTERNAL TRAINING ACTIVITIES**
- ECPE Workshop, 'New Technologies for Medium-Frequency Solid-State Transformers' (15/02/19, 15h, Lousanne)

#### PhD program in Electrical, Electronics and **Communications Engineering**