Power converter design for eMotor test rig

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***Abstract*—This thesis aims to design two PCBs to control an 800V inverter. One board is the "DC-side board" and it is responsible of managing the high voltage side of the system, so the pre-charge and discharge of the DC bus and the external auxiliary components. The other one is the control board and it acquires and processes all the signals coming from the sensors such as, encoder, current, temperature and voltage in order to regulate the inverter.**

I. Introduzione

The rise of power electronics has revolutionized energy transformation, control, and distribution. Inverters, particularly those operating at higher voltages like 800V, have garnered significant attention, especially in automotive applications, due to their potential to enhance charging speeds and energy efficiency. This thesis explores how to design and optimize a control board for an 800V inverter, crucial for ensuring efficient and safe energy conversion. The current inverter configuration necessitates a control board to regulate various processes, including power flow management, temperature monitoring, communication interfaces, and optimization algorithms. However, the existing setup presents several challenges, such as single-ended encoder signaling, absence of EMI filters, limited external connectors, microcontroller unit (MCU) not surface mounted and inadequate DC-side management.

II. DC-side board

The DC side board is a type of electronic circuit board. It helps control and manage the power on the DC side of the inverter. It's mainly used to start up and shut down the inverter and to power auxiliary components like cooling fans and relays.

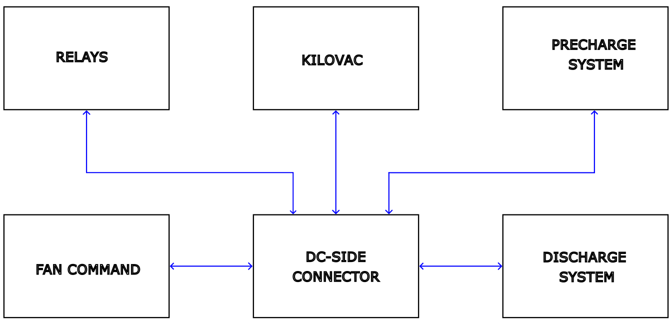

Figure 1: DC-side control scheme.

The DC-side board manages 5 different tasks:

1) **Kilovac regulator**: The Kilovac LEV200 is an high voltage relay used as a general switch in this application. The Kilovac regulator system has been made to better control the voltage across the coil, this helps reduce the power consumption of the device. Once the circuit is running at steady state, the voltage is lowered to 3V (minimum required voltage) from 12V helping reduce the consumption from ≅ 13W to ≅ 0.8W
2) **Precharge system**: A precharge system is commonly employed in DC link circuits to safely and slowly charge the capacitors before connecting them to the power source. This is crucial for various reasons, such as minimizing inrush current. When capacitors are first connected to a power source, they behave like a short circuit until fully charged. This sudden rush of current can harm components, so precharging prevent this issue.
3) **Discharge system**: The discharge system is a circuit designed to release the energy stored in the DC link. It plays an important role in managing the DC side and is crucial for safety.
4) **Relays command**: The relay control block is responsible for managing auxiliary devices like extra cooling systems or other external equipment needed during experiments.
5) **Fan command**: It's been included an extra fan in the design to improve thermal dissipation. Therefore, the enabling circuitry for this fan is included in this block.

The final result of the desing of the control board is shown by fig.2:

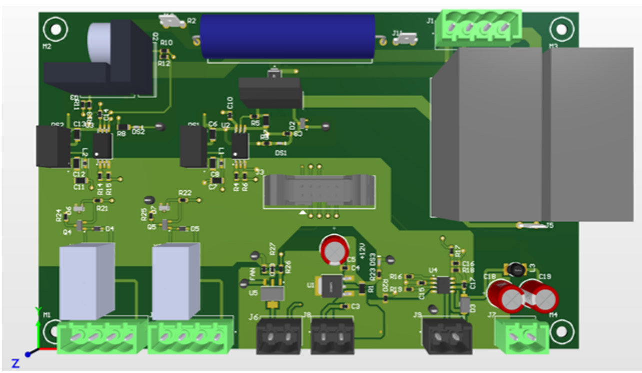

Figure 2: Dc-side 3D design.

III. Control Board

The inverter had its original control board with an MCU and limited functionalities. However, with the inclusion of several new components, it was evident that the current board size was insufficient. Consequently, the new control board has been redesigned to be positioned higher, with the flexibility to extend beyond the confines of the inverter box.

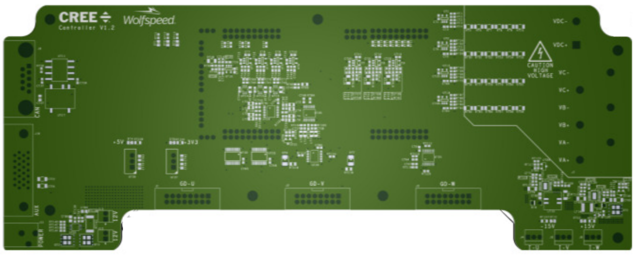

Figure 3: Original control Board.

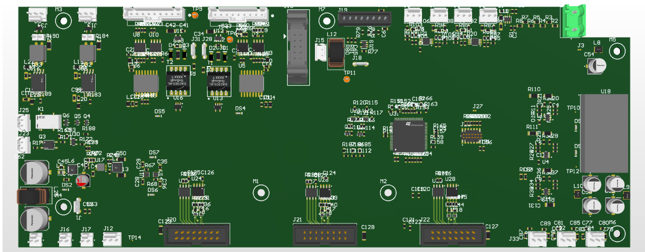

Figure 4: New control Board.

The main functions of the new control board are:

- **Power Supply:** The control board requires a stable and reliable power supply to operate. This power supply includes voltage regulation and filtering to ensure clean power is delivered to the control electronics and to the gate drivers.
- **Gate Driver Interface:** The control board interfaces with the gate drivers, which are responsible for controlling the switching of power MOSFETs in the inverter.
- **Feedback Circuitry:** The control board includes feedback circuitry to monitor various parameters such as current, voltage, temperature, and fault conditions within the inverter system. This feedback is essential for closed-loop control and protection mechanisms.
- **Microcontroller:** The microcontroller used to implement control algorithms, process sensors data, and generate control signals with precise timing and accuracy.
- **Communication Interface:** The control board features communication interfaces such as UART and CAN bus for external communication with other devices or systems, enabling monitoring, configuration, and diagnostics.
- **Protection Circuits:** To ensure safe and reliable operation, the control board uses protection circuits to detect and respond to overvoltage, overcurrent, overtemperature, and short-circuit conditions. These circuits trigger fault shutdowns or activate protective measures to prevent damage to the inverter system.

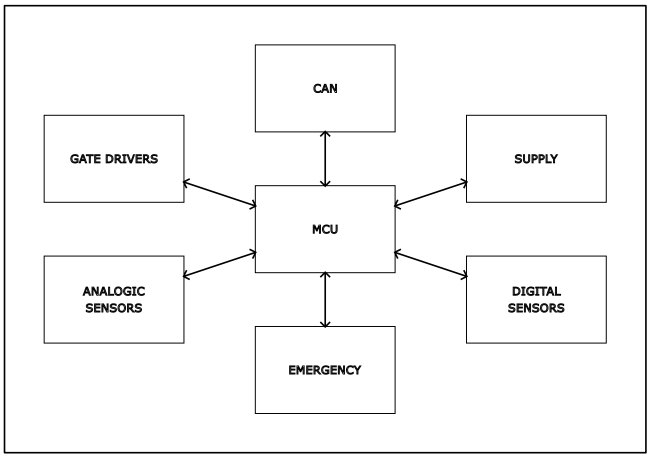

Figure 5: Block diagram of the control board..

The original control board already had:

- Current, voltage and internal temperature sensors;
- Gate driver connectors and their signal conditioning circuits;
- CAN circuitry;

While the main features added to the new one are:

- External temperature sensors (PT100);
- Microcontroller embedded onto the board with its circuitry;
- Emergency circuits;

IV. Conclusions

In conclusion, this thesis focuses on designing and improving a control board for an 800V inverter, a critical aspect of power electronics. The rising demand for higher voltage systems, especially in automotive applications, underscores the importance of robust control mechanisms.

The control board serves as the "brain" of the inverter, overseeing vital tasks such as power regulation, temperature control, communication interfaces, and optimization algorithms. Addressing shortcomings in the previous configuration, including issues with encoder signaling, EMI filters, external connectors, and safety mechanisms for the high-voltage DC side, is crucial for advancement.

The proposed redesigned control board offers a comprehensive solution by integrating the MCU directly onto the board, redesigning power supply systems, and adding safety features like emergency sequences and circuit breakers. This enhances functionality, versatility, and safety standards.

Overall, the thesis contributes to the project by developing circuitry for the DC-side board, redesigning the control board, selecting suitable components, and creating an emergency circuit. Future work includes physically realizing and testing these boards in the PEIC laboratory