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FACULTY OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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A Single-Phase Reactive Power Compensator with Reduced-Size Film Capacitors and Active Power Decoupling Control

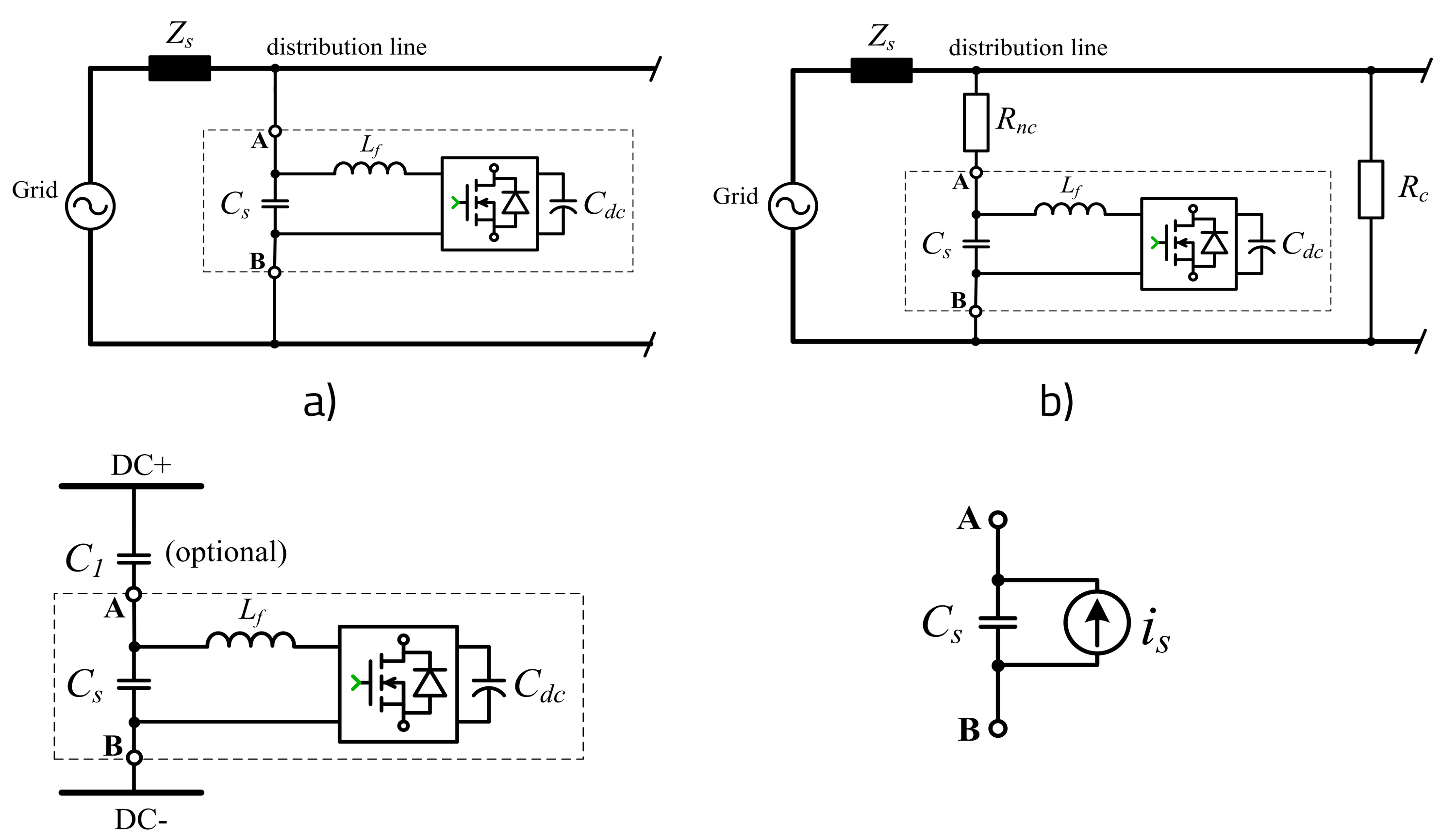
Ioan Șerban, Ronald Musona
Department of Electrical Engineering and Applied Physics
Transilvania University of Brasov, Romania
ioan.serban@unitbv.ro

ABSTRACT

Enhancing the reliability of power electronic systems poses a significant challenge, prompting intensive investigation into both control and hardware solutions. To address this, the paper proposes a single-phase reactive power compensator that integrates an H-bridge inverter with reduced-size film capacitors and an active power decoupling control. The proposed compensator offers a notable advantage by eliminating the necessity of electrolytic capacitors on the inverter DC-link, achieved through the adoption of a minimalist power decoupling solution. This technique relies exclusively on durable film-type capacitors of reduced size and requires no additional power semiconductors. The proposed system's performance was assessed through simulation results.

INTRODUCTION

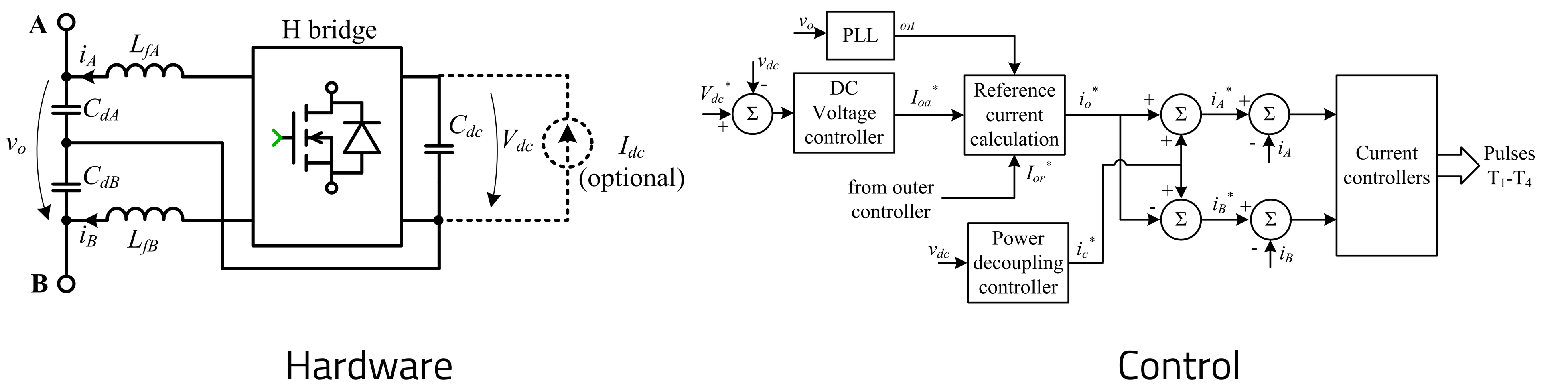
- Single-phase inverters are extensively employed in small-scale applications, particularly for renewable energy sources (RES) and for power conditioning purposes;
- The inherent double frequency power pulsation power pulsation necessitates an energy buffering component, frequently achieved using electrolytic capacitors.
- Despite their low cost and high power density, electrolytic capacitors have a limited lifespan, especially in high-temperature conditions;
- Active power solutions leveraging power electronics and compact film capacitors focus on reducing the physical size of inverters required capacitor, while maintaining energy buffering capabilities.
- Besides interfacing RES, single-phase inverters have also been adopted in power quality improvement technologies, such as *reactive power compensators*, *electric springs* and *active capacitors*.
- In all presented structures, the active cell (outlined with a dotted line) is similar, comprising a capacitor in parallel with a current-controlled single-phase inverter, typically an H-bridge.
- By leveraging the advancements in the field of active decoupling techniques for single-phase inverters, an enhanced solution for the active cell utilized in such applications is proposed in this paper.



Targeted applications by the proposed active cell (single-phase): a) reactive power compensator; b) electric spring; c) active capacitor; d) equivalent scheme of the active cell.

PROPOSED SOLUTION

- The main advantage of the proposed solution relies in its minimalist hardware structure, which does not require any additional power semiconductors;
- Two film capacitors (C_{dA} and C_{dB}) are employed, both as input capacitor of the active cell and as decoupling capacitors used by the adopted power decoupling method.
- A small capacitor C_{dc} (about one-tenth the size of the electrolytic capacitor in conventional implementation) is needed on the DC link;

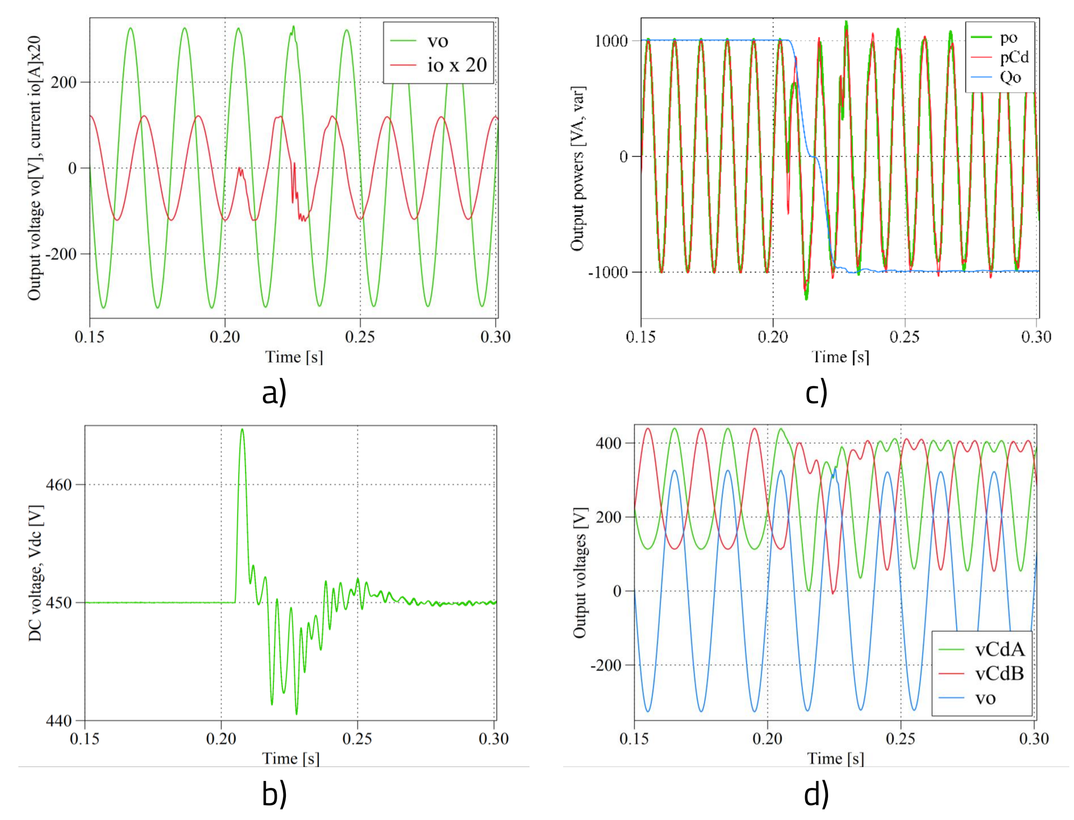


RESULTS

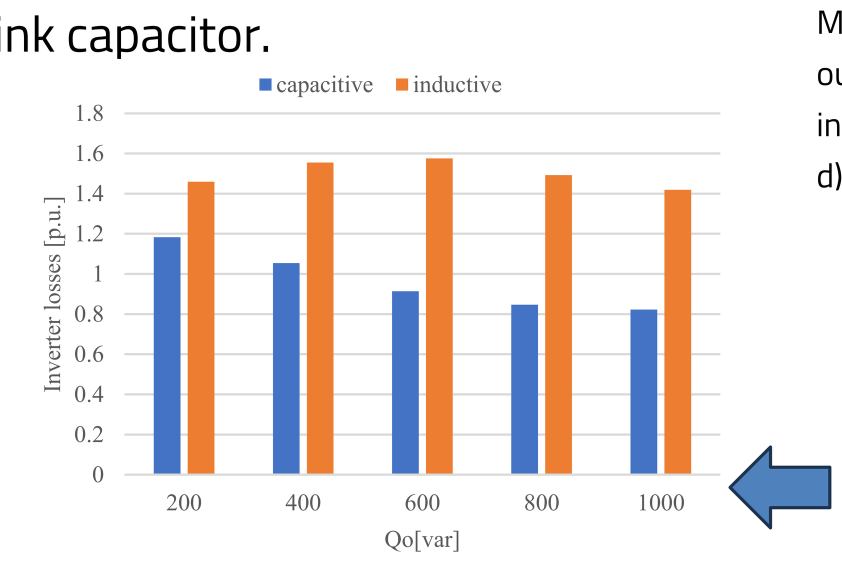
- To demonstrate the functionality of the proposed solution, the reactive power reference is switched between inductive and capacitive modes, at a rated power of 1kVA;
- The transitory regime leads to a slight deviation of the DC-link voltage, which has no impact on the control of the differential output voltage (v_o).
- The proposed control method ensures that the entire output power pulsation is directed through the two decoupling capacitors ($p_o = p_{Cd}$, where $p_{Cd} = p_{Cd1} + p_{Cd2}$) rather than the DC-link; thus, the DC-link voltage can be kept constant even with a small DC-link capacitor.

MAIN SYSTEM PARAMETERS

Parameter	Value
Output rated apparent power	S_o = 1 kVA
Output rated voltage and frequency	V_o=230V; f_o=50Hz
DC voltage	V_{dc} = 450 V
Filter inductances	$L_{fA} = L_{fB}$ = 440 μH
Decoupling capacitors (film type)	$C_{dA,}=C_{dB}$= 60 μF
DC-link capacitor (film type)	C_{dc}=100 μF



Main waveforms: a) output voltage and current (x20); b) DC-link voltage; c) output powers: p_o (instantaneous output power), $p_{Cd} = p_{CdA} + p_{CdB}$ (sum of the instantaneous powers of decoupling capacitors), Q_o (output reactive power); d) output voltages.



Inverter losses for variation of output reactive power (capacitive and inductive), normalised to the losses of conventional inverter.

Considering implementation with SiC MOSFETs, when the operation is predominantly capacitive (which is typically the case for static compensators), the proposed topology exhibits lower losses compared to the conventional inverter.

CONCLUSIONS AND FUTURE PROSPECTS

- The paper proposes an improved single-phase inverter adapted for applications requiring controlled reactive power, like static compensators;
- The solution implements a minimalist active decoupling technique, eliminating the need of electrolytic capacitors and additional semiconductors;
- Simulation results demonstrate that the inverter, with the proposed active power decoupling, effectively controls the output reactive power;
- Further research aims to experimentally validate its performance under practical disturbances, while also exploring advancements in gallium nitride transistor technology for increased power density and efficiency.