A Novel Low-THDi Rectifier for Electrolysis: Controller Optimization using C-HIL Simulations

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1 Context

The **demand** for renewable energy production and **high-power (>MW) rectification ↗ .**

In particular, for the production of **green H_2**, which is being considered for the decarbonization of certain industries.

Power Quality challenges arise due to non-linear current waveforms caused by rectifiers.

→ Total Harmonic Distortion of the current (THD_i) $\propto P$

There is a need for building **more efficient** rectifier that **disturb less the grid** !

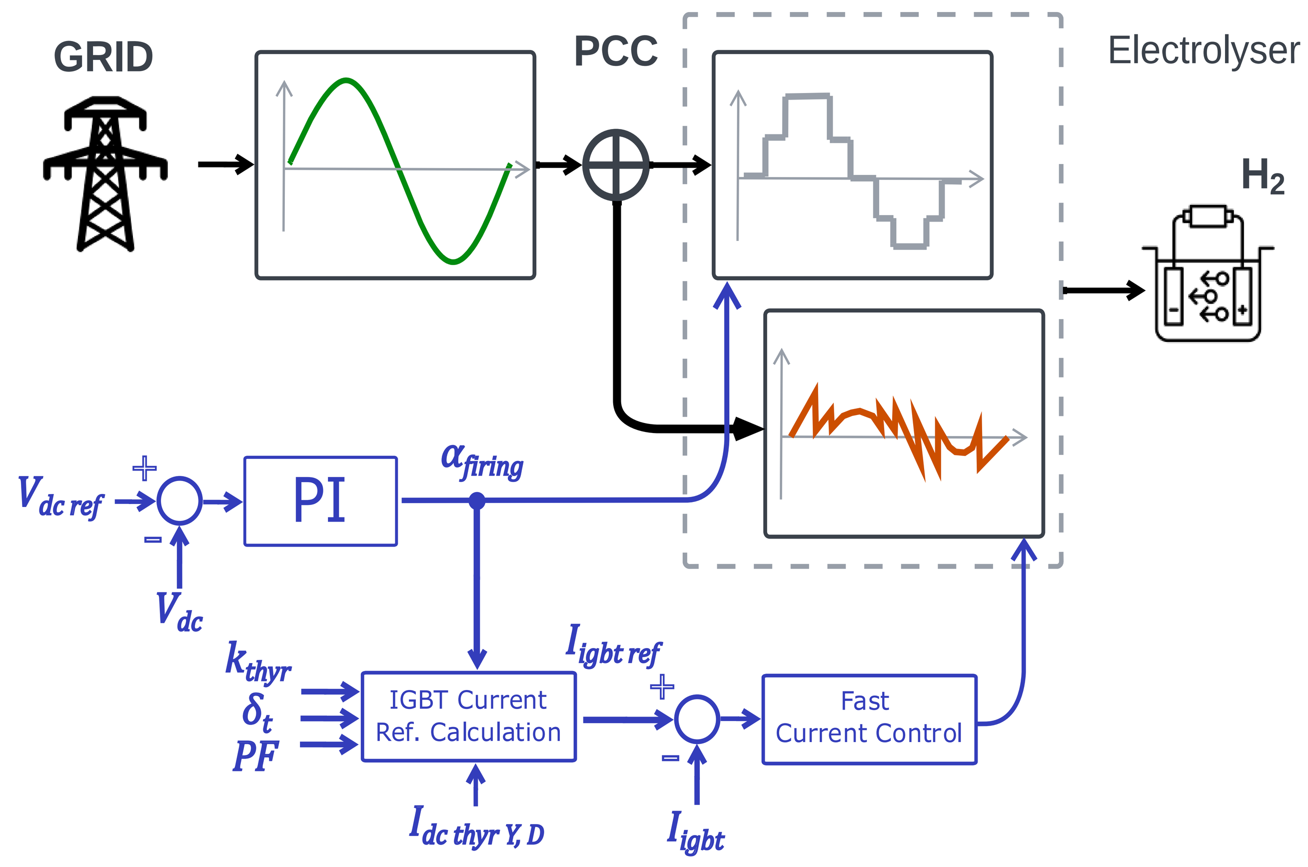
2 Novel Rectifier Architecture

We propose a novel rectifier architecture based on the classical **12-pulses thyristors rectifier combined with IGBTs inverter.**

This architecture combines thyristors, STATCOMs, and active power filters benefits:

1. high P transfer relative to cost
2. reactive power control
3. harmonics compensation

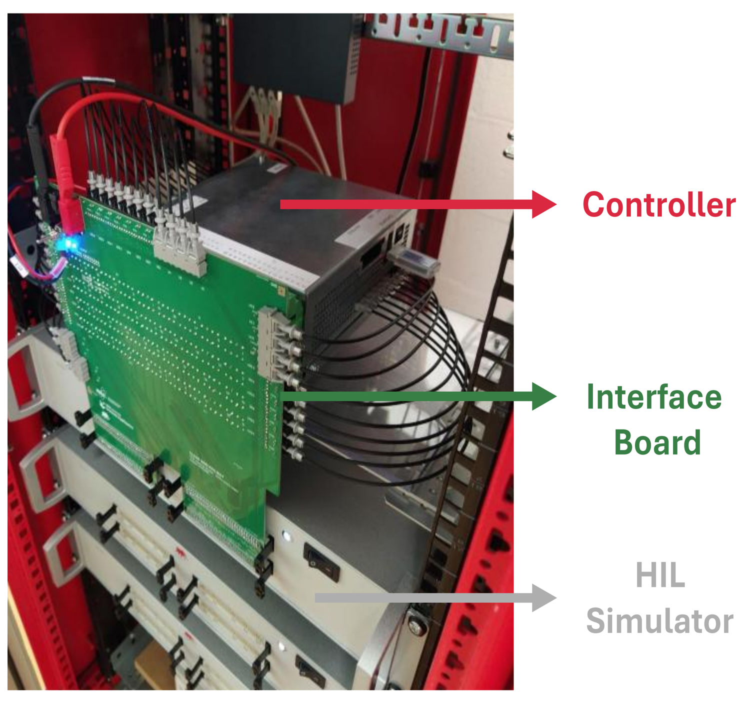
in a single device.



This is achieved by connecting the DC bus of the VSC inverter directly to the load.

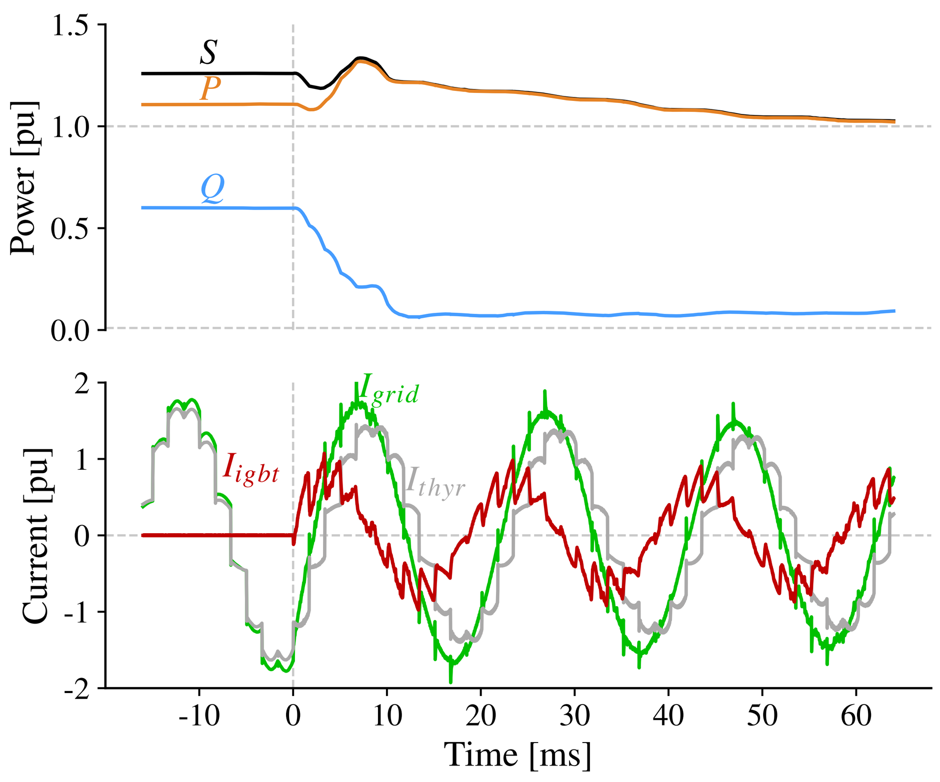
Single device = **single brain**
→ Relative Knowledge ↗ = **advanced control**

3 Controller-Hardware In the Loop (C-HIL) Validation



The designed rectifier is modeled and configured in a **C-HIL platform for fast validation and optimization** of the digital controller.

FPGA based controller
Two execution rates:
1µs & 50µs
IGBTs switching ~ 9 kHz

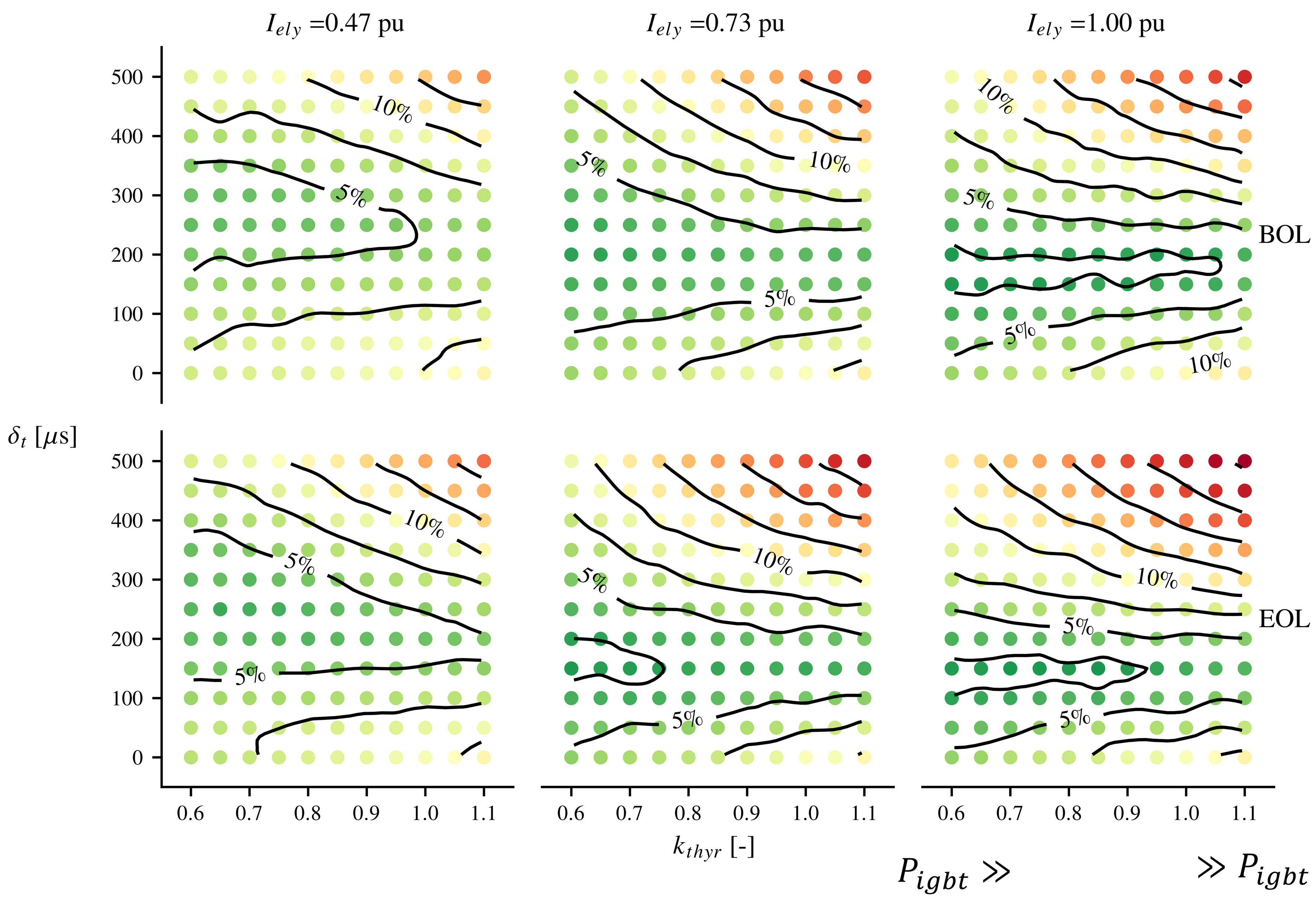


Controller Principle:

1. Control of V_{dc} with a PI (~ Control of P_{dc})
2. Estimation of I_{thyr} at PCC
3. Computation of $I_{igbt\,ref}$ for a given PF
4. Fast Control of I_{igbt}

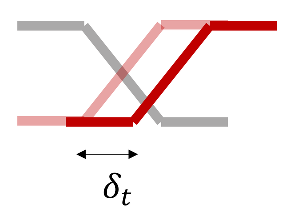
Validation :
PF is controlled to 1 ($Q \to 0$)
THD_i drops from 12% to **3%**

4 THDi Minimization



Optimization of 2 control parameters using C-HIL simulations :
k_{thyr} ~ coefficent controlling P sharing between thyristor and IGBT bridges.

δ_t ~ time anticipation to compensate steep edges of I



Test case :
Beginning and End of Life (BOL & EOL) electrolyzers at 3 different level of H_2 production.

Results :

1. Highly sensitive to δ_t but optimal δ_t depends on the load.
2. Weakly sensitive to age of the electrolyzer.
3. k_{thyr} impact THD_i performance at lower H_2 production.
4. Optimization process reach $THD_i < 2{,}5\%$

5 Conclusion

C-HIL simulations enable rapid optimization of power converters and can reveal unforseen behavior to the designer.

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