# Model Predictive Control applied to Hybrid Converter, based on SiC-MOSFET and Si-IGBT

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## 1. Context

Currently, MW scale Wind Turbine Converters (WTC) operate with Si-IGBT devices that are controlled by power width modulation (PWM). Switching losses of these semiconductors limit the current PWM frequency to 1.5-3kHz resulting to require bigger size of passive filter elements.

SiC-MOSFET devices have been increasing their current capabilities to the point to be considered for MW-scale converter applications. SiC-MOSFET devices offers lower conduction losses and a high-speed switching leading to a reduction of power losses compared to an equivalent rating IGBT device [1,2]. Both characteristics enable to increase switching frequencies allowing for reduction AC filter size without compromising the converter efficiency or keep filter the same and obtain higher efficiency.

However, currently SiC-MOSFET devices have prices of around 4 times to Si-IGBT devices at same current ratings. Therefore an idea of studying a converter based on the synergy between both semiconductors seems attractive.

A main converter connected in shunt with an auxiliary converted is being studied here, called hybrid converter (HC) [3]. See Fig. 3. The main converter deals with the major current and the aux. converter would compensate the harmonic current levels.

## 2. Methodology

Model predictive control(MPC) is based on the customisation of a cost function and then select the minimum cost which influences future actions. This control technique enables to control multiple variables, can add system constraints and perturbations[4]. Here MPC is applied to control both converters.

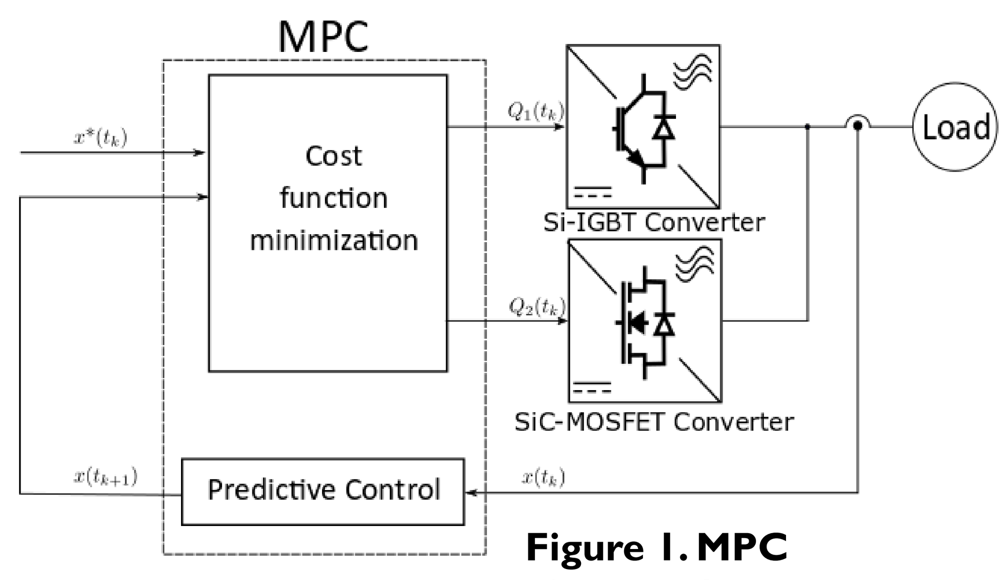


**Figure 1. MPC**

**Figure 2. dSPACE MicroLabBox**

First HC is modelled in discrete time domain to perform MPC. The cost function is customised to give more weight on the error of the three phase grid current. It also controls the switching losses by adding a new weighting factor. This enable to switch much faster SiC-MOSFET than IGBT devices. Each sample period, the algorithm calculates the minimum cost. Fig. 1.

## 3. Simulation results

First simulations results offer a good electrical quality power.

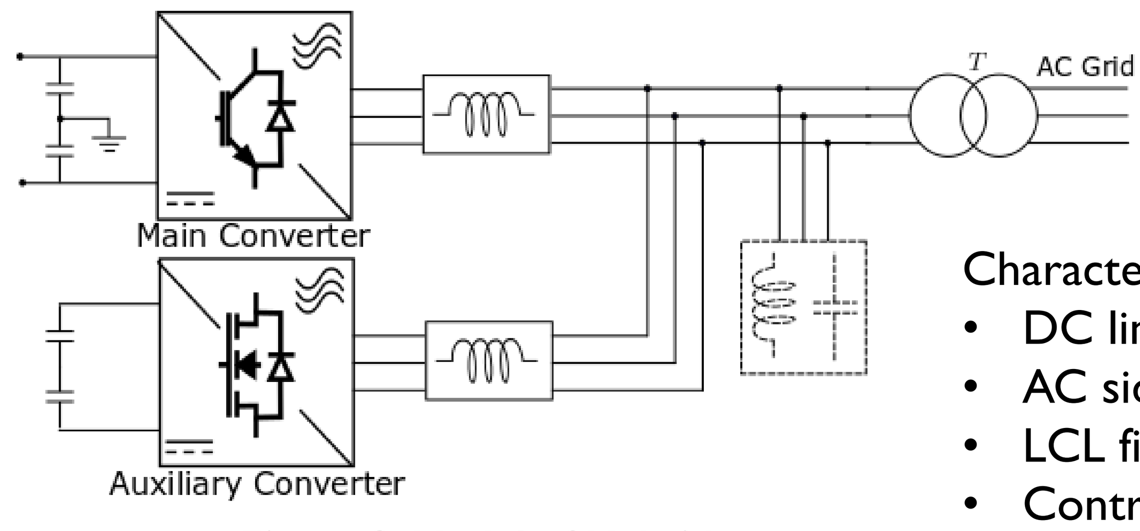


**Figure 3. Model of Hybrid Converter**

Characteristics of HC:

- DC link decoupled
- AC side coupled
- LCL filter
- Controlled by MPC

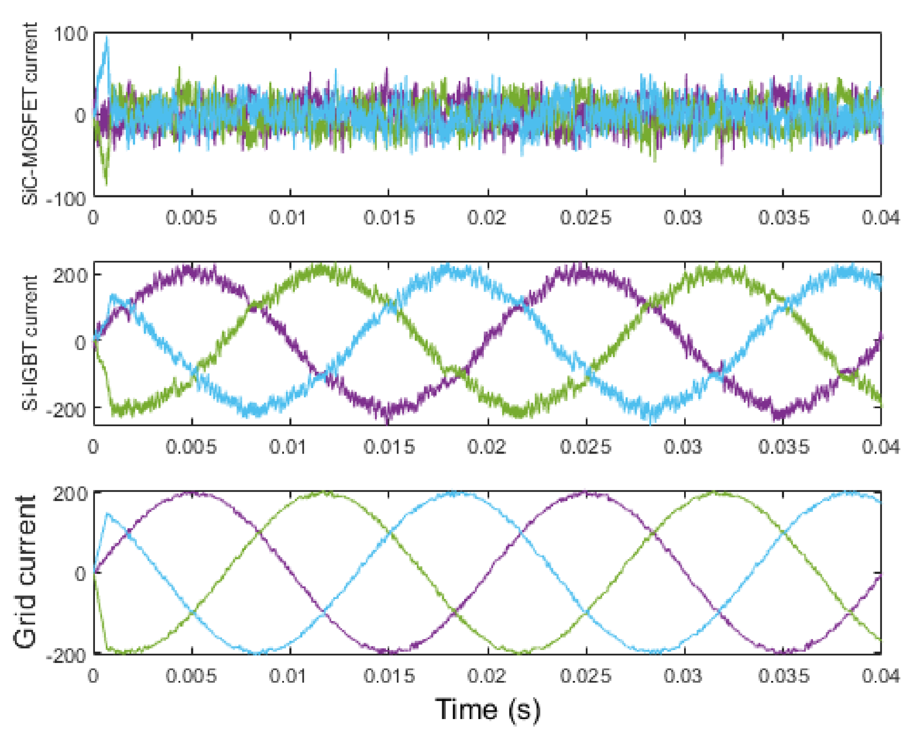


**Figure 4. Hybrid Converter MATLAB simulations**

Fig. 4 shows IGBT converter deals with major current and MOSFET compensates the ripple current. The sum of both currents offer a good electrical quality power, grid current.

## 4. Hardware implementation

A 90kVA hybrid converter prototype test-bench is being built currently. It contains a rectifier and 2 inverter units. See Fig. 5. The main inverter will be a pre-built SemiKube module based on Si-IGBT power modules along with a custom built auxiliary inverter based on SiC-MOSFET modules. The system will be controlled using a dSPACE MicroLabBox controller.

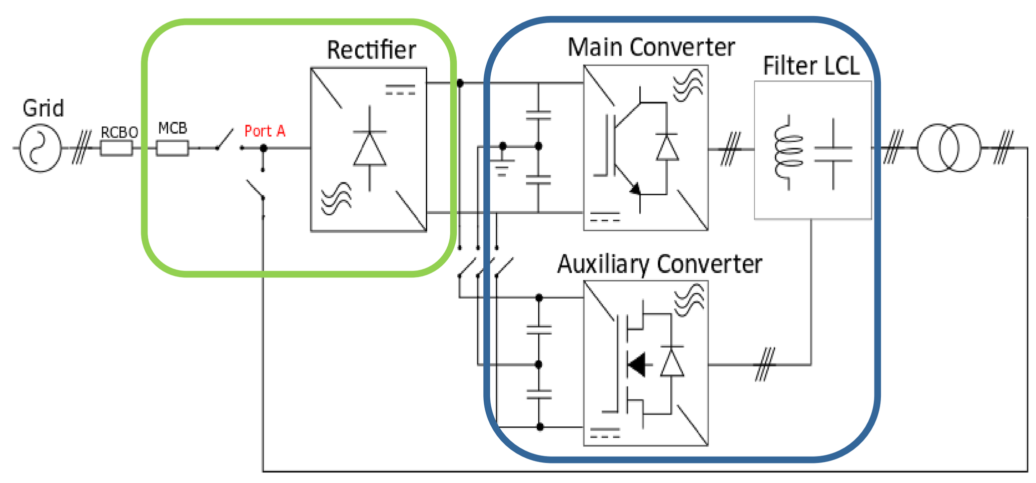


**Figure 5. Hybrid converter prototype**

Rectifier module is currently in commissioning phase and it is enclosed in a cabinet of size: Width 800mm, deep 600mm, height 2000mm. Fig. 7.

**Figure 6. SemiKube Module**


**Figure 7. 90 kVA Rectifier converter. Built with Z. Blatsi**

## 5. Conclusion

Simulation results shows SiC-MOSFET modules have a higher average switching frequency than IGBT modules which proofs MPC is used to optimize switching pattern. Other potential benefits of MPC is a much faster response to dynamic events than traditional controls. Having a SiC-MOSFET converter that behaves as an active filter, allows to obtain improved electrical power quality, therefore it implies less electrical passive filter elements. In general terms, HC would potentially reduce the overall cost at system level.

Reference

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