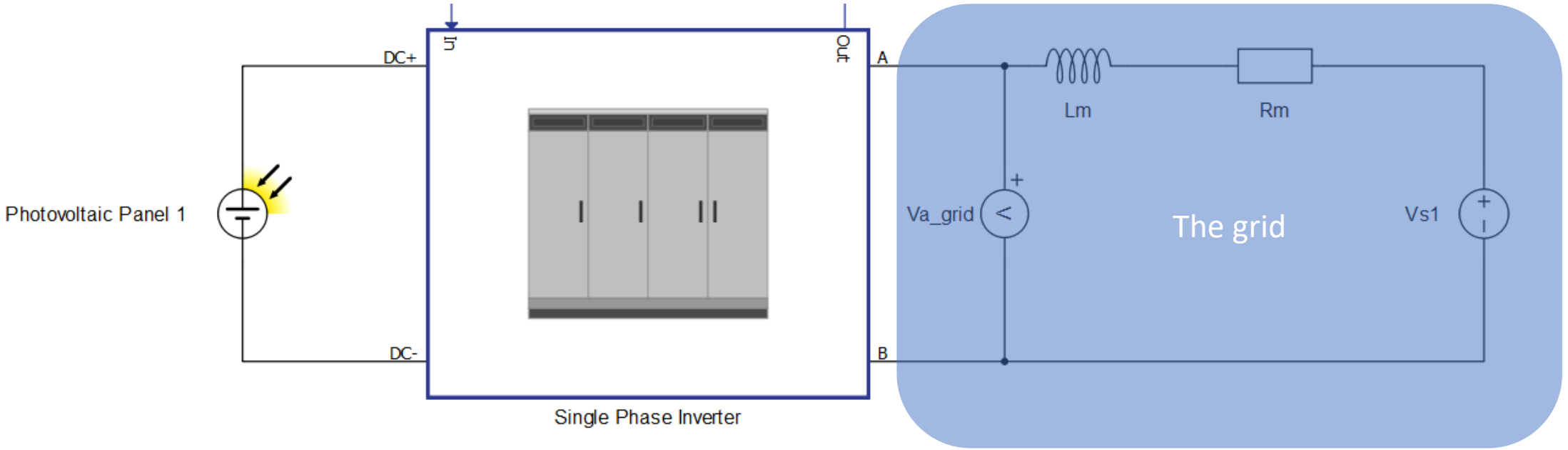
PV inverter control

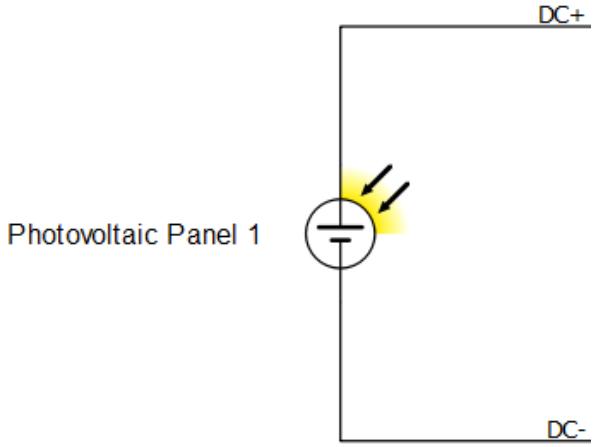
Typhoon HiL implementation explanation

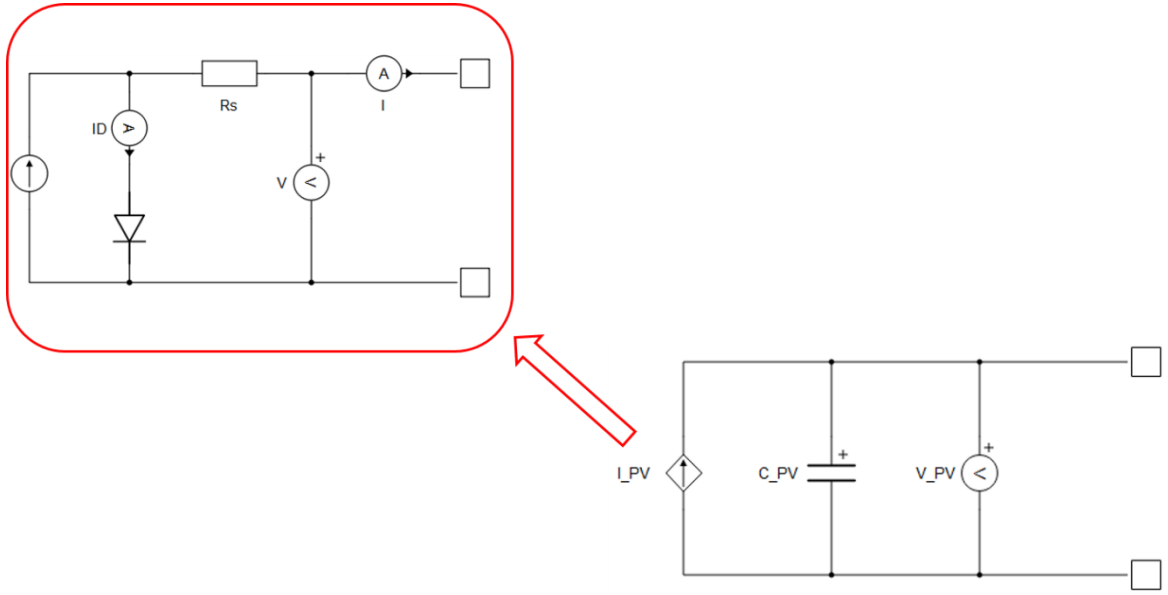
The plant

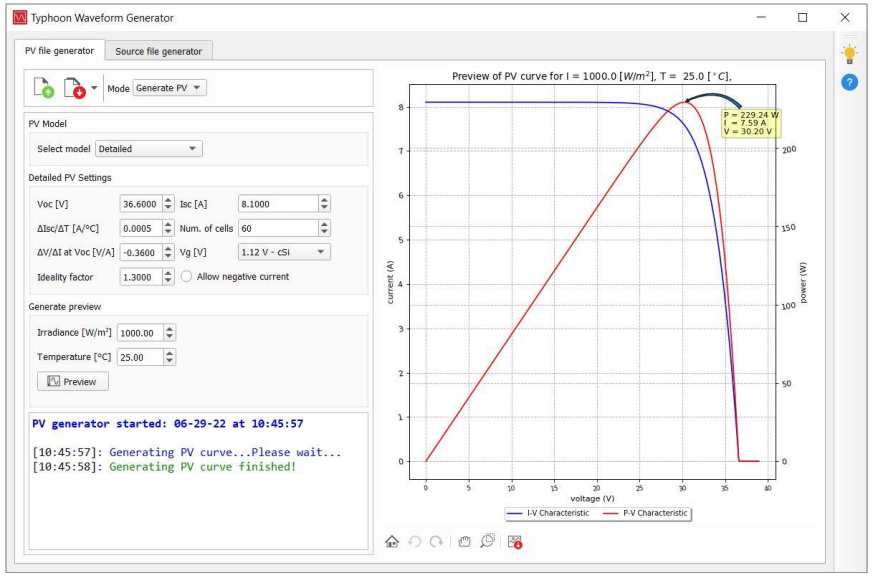

Photovoltaic Panel 1
DC+
DC-
In
Out
A
B
Lm
Rm
Va_grid
Vs1
The grid
Single Phase Inverter

Model of PV panels

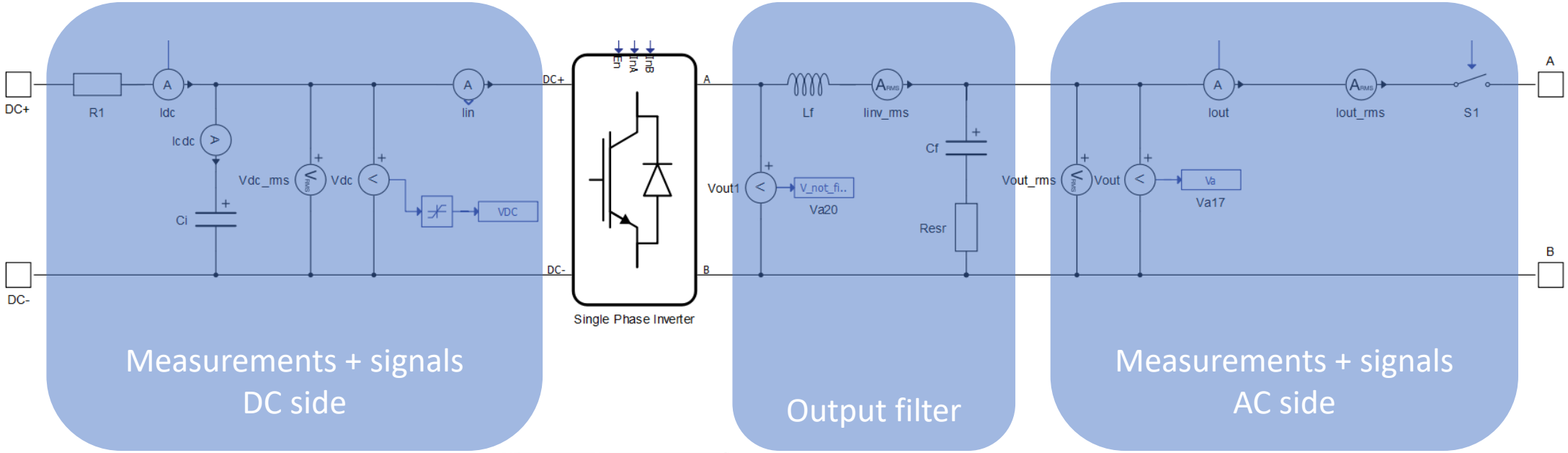
- Classical current source + diode model
- Models the I-V curve

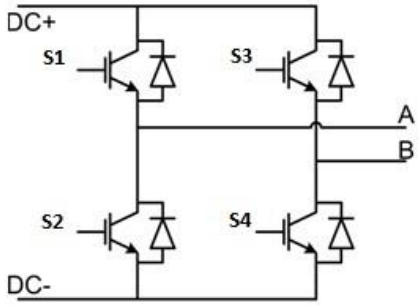




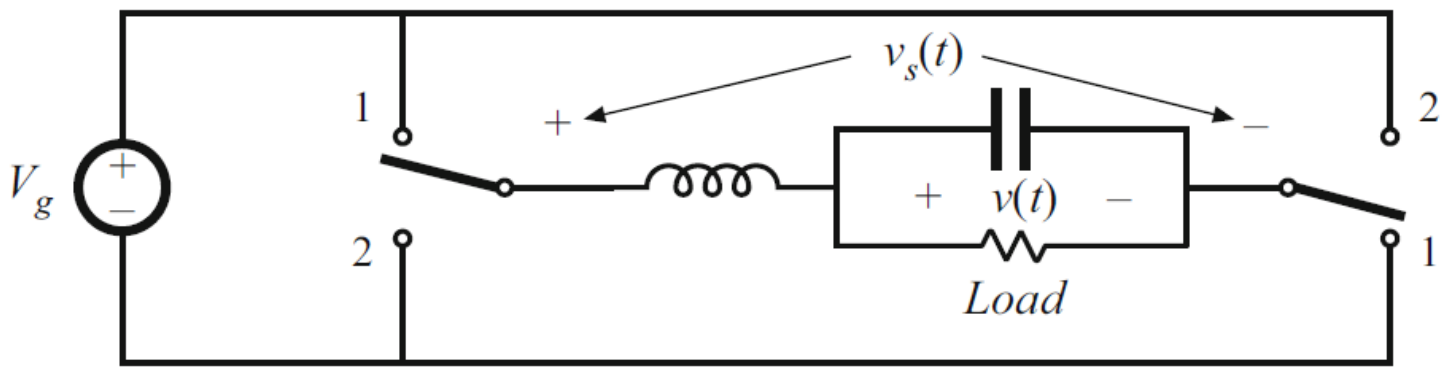


Let’s dive into the inverter – electrical part

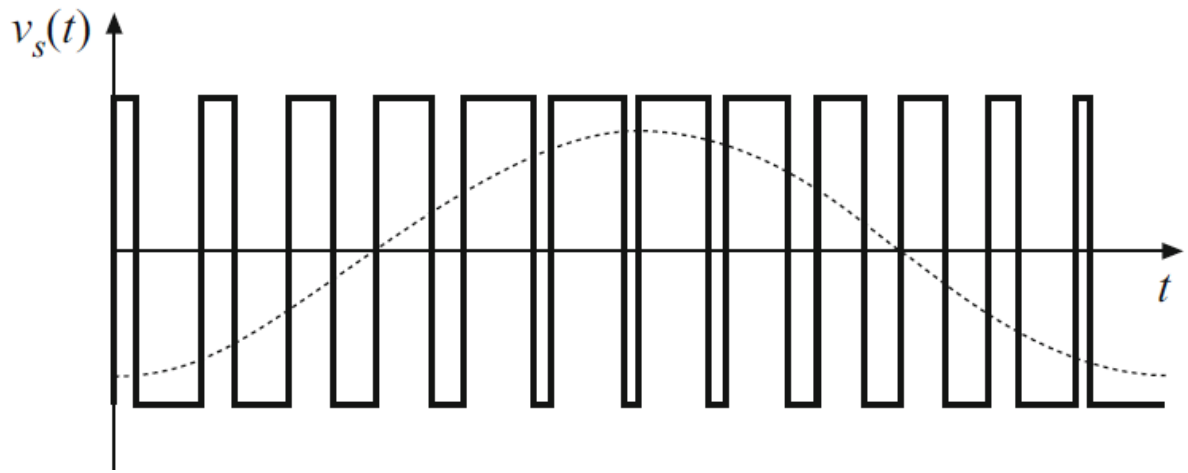




(a)



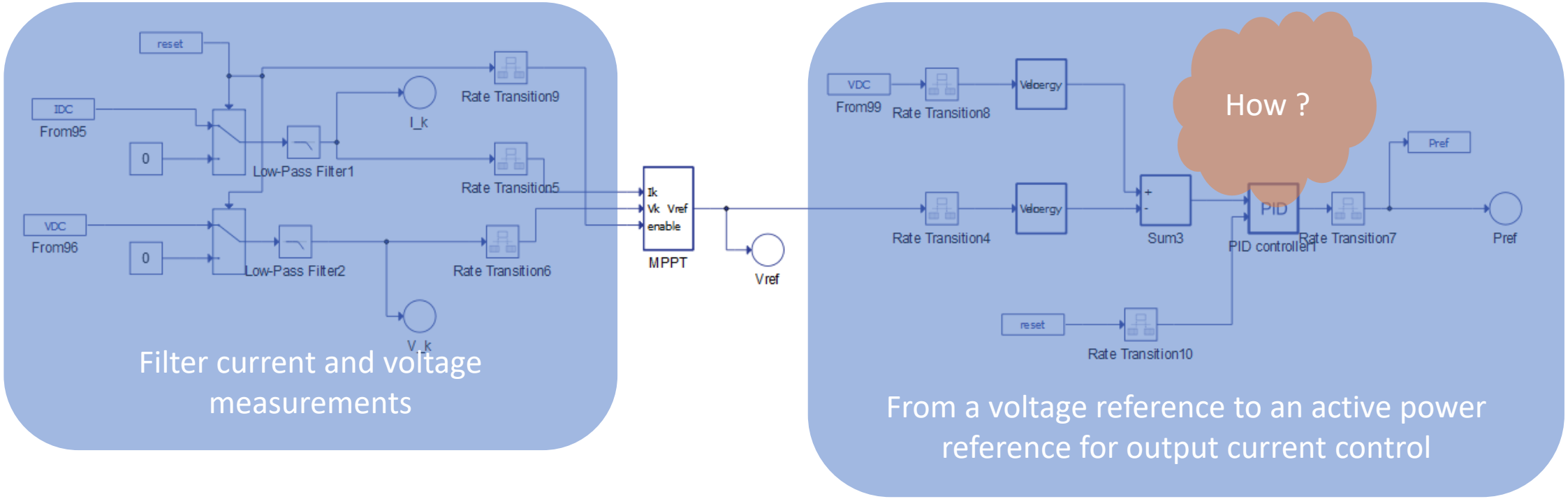
(b)



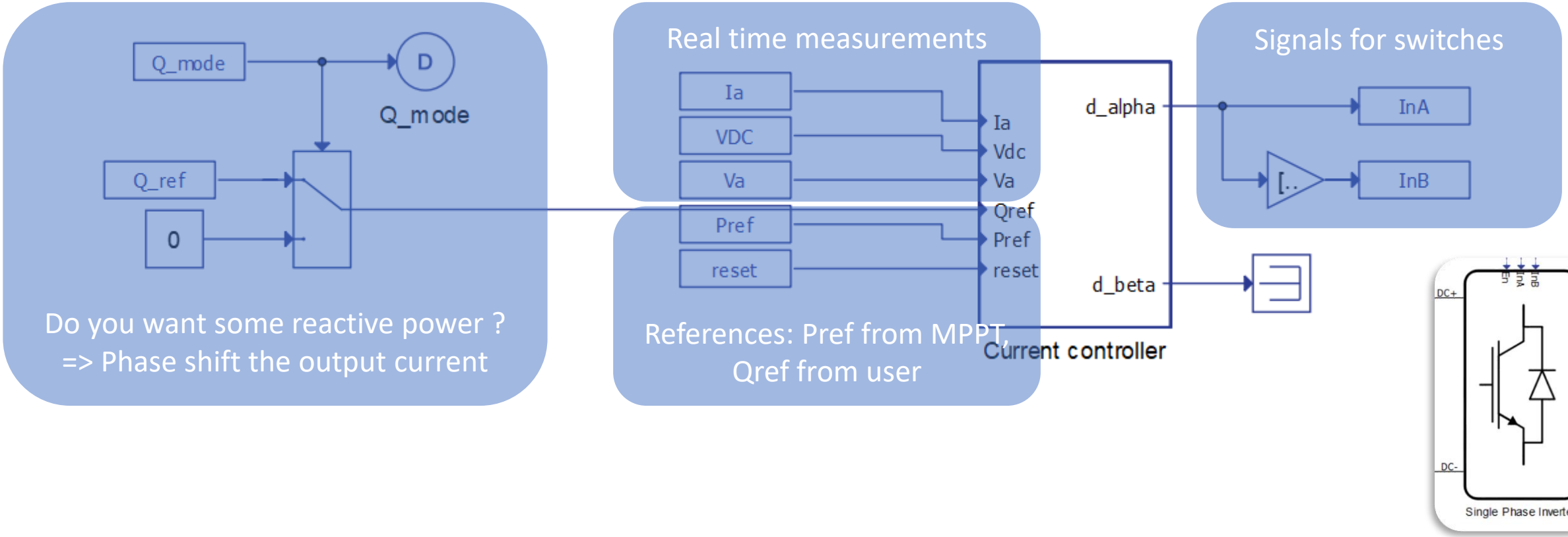
Let’s dive into the inverter - control

- How is the inverter controlled?
  - This is a grid-following converter
  - It thus requires active and reactive setpoints P_ref and Q_ref
    - P_ref is obtained from MPPT, relatively slow control loop
    - Q_ref is set by the user here, but could be the result of a voltage droop controller
  - It « reads » network voltage V_A -> for reference
  - It « reads » the network current I_a -> for feedback control
  - It generates the signal to modulate the switches so as to produce the right I_a, in amplitude and phase.
    - This is a fast control loop
  - Accounting for the limits of the inverter (S_a)

MPPT control



Current control



Current controller – Single phase *dq* current control algorithm

Phase lock loop + dq transform => measure the voltage frequency, project the voltage on d and q axes, provide a phase reference for the current

DQ transform for the current

dq transform

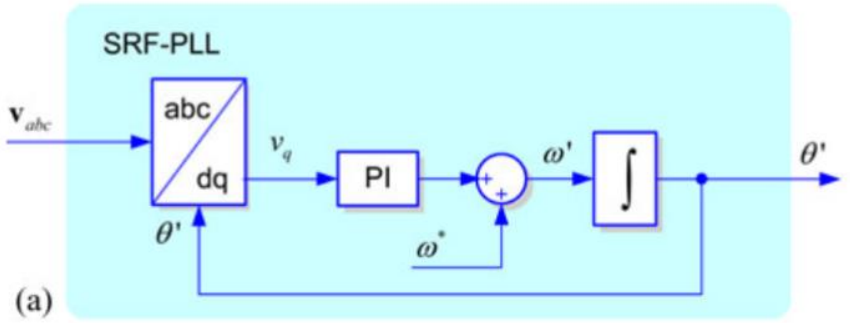
- Instead of working with instantaneous values that change all the time, apply a transformation to obtain important information for control:
  - How is the grid current phasor placed with respect to voltage phasor
  - “Kind of equivalent to working in DC”
- The *dq* transform is the composition of the Clarke and Park transforms
  - Clarke transform: “Encode time-varying values on fixed $\alpha - \beta$ axes (2D)”
  - Park transform: Let the axes rotate to “get rid of the $e^{j\omega t}$”

- See for instance: O’Rourke, C. J., Qasim, M. M., Overlin, M. R., & Kirtley, J. L. (2019). A Geometric Interpretation of Reference Frames and Transformations: Dq0, Clarke, and Park. *IEEE Transactions on Energy Conversion*, *34*(4), 2070–2083. https://doi.org/10.1109/TEC.2019.2941175

Phase Lock Loop (PLL)

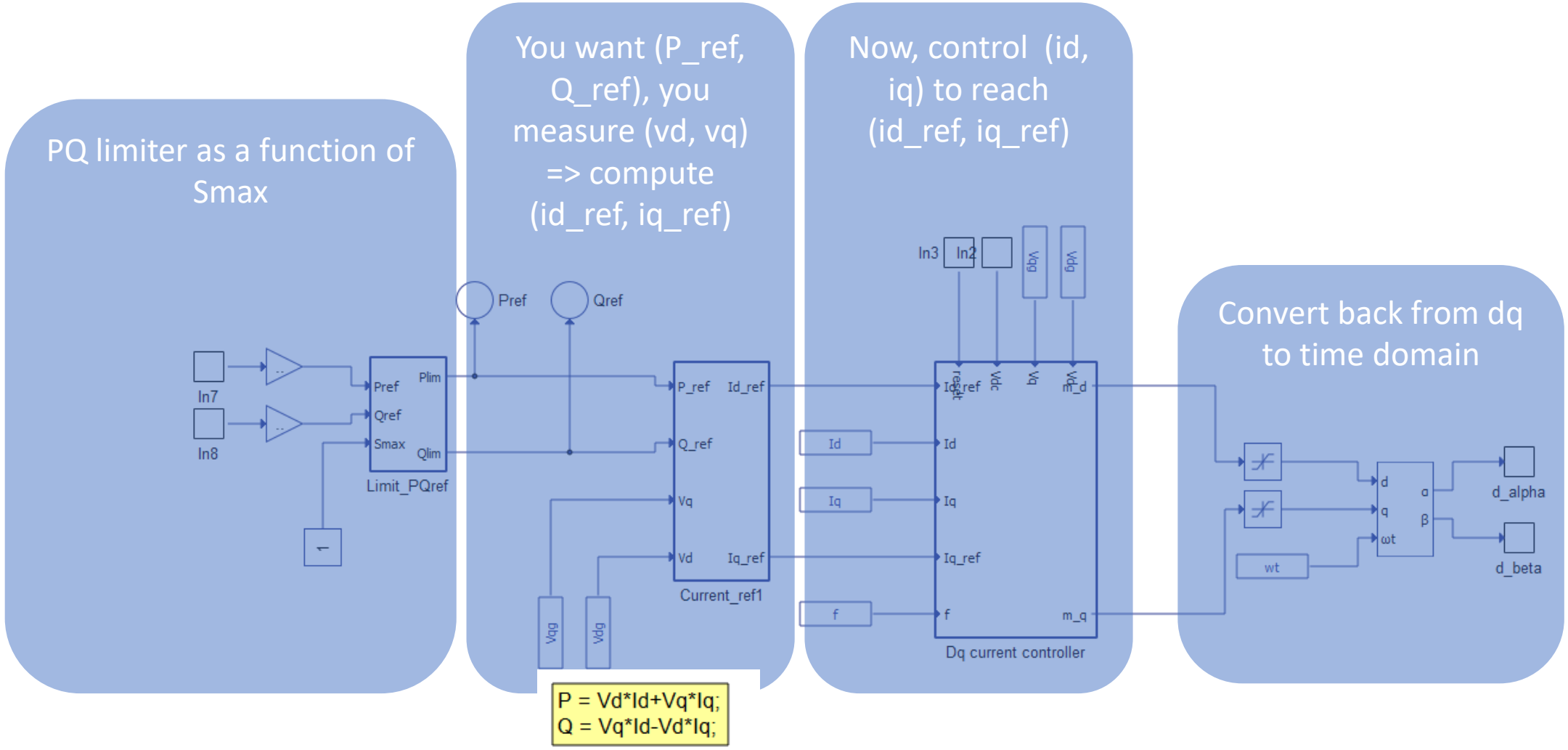
- The *dq* transform requires
  - a grid angle
- This is obtained using a PLL block (phase lock loop)
- Outputs the grid frequency as a by-product.

- *dq* and PLL blocks can be intertwined:

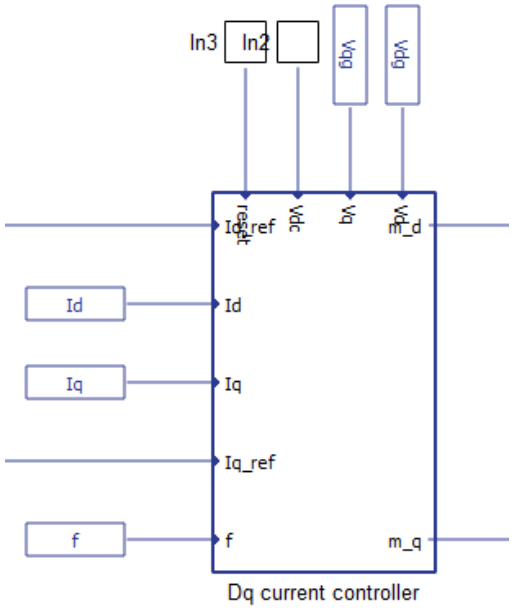


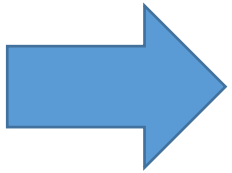
See Rocabert, J., Luna, A., Blaabjerg, F., & Rodríguez, P. (2012). Control of power converters in AC microgrids. *IEEE Transactions on Power Electronics*, *27*(11), 4734–4749. https://doi.org/10.1109/TPEL.2012.2199334

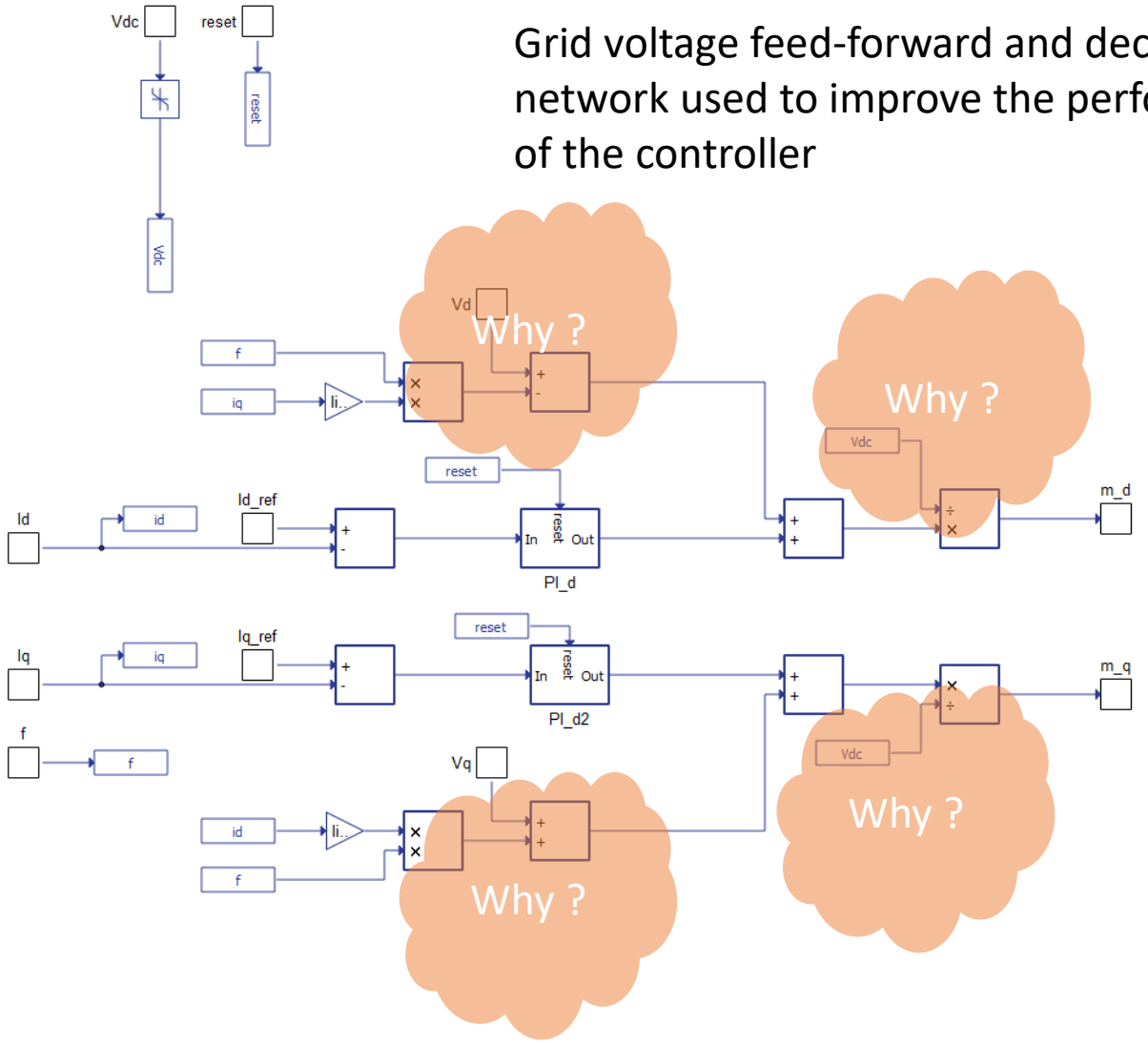
Current controller – Single phase *dq* current control algorithm



DQ Current controller







Grid voltage feed-forward and decoupling network used to improve the performance of the controller

Power measurement