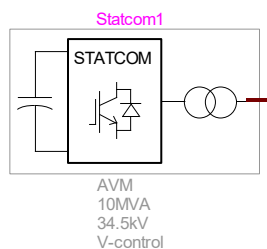


STATCOM



STATCOM	1
1 Description	1
1.1 Parameters	1
1.1.1 General tab	1
1.1.2 Transformer	3
1.1.3 Control Converter	3
1.2 Reactive Power Control	4
1.2.1 Outer loops	4
1.2.2 Inner loops	5
1.2.3 Current limiters	6
1.3 Phase Lock Loop (PLL)	6
1.3.1 PV harmonic model	7
2 References	7

Hossein Ashourian, Ulas Karaagac, Henry Gras, Jean Mahseredjian, 8/25/2020 10:45 AM

1 Description

This device is an implementation of an aggregated STATCOM model. It is valid for time-domain, frequency-scan and load-flow simulations. It may also be used for a single- STATCOM.

1.1 Parameters

1.1.1 General tab

The parameters on the Data tab are:

STATCOM general parameters

- **Number of parallel STATCOMs:** Number of parallel STATCOMs. The total rated power is the number of STATCOMs multiplied by the STATCOM rated power. To model a single STATCOM, set this input to 1.
- **Nominal Frequency:** Electrical power frequency
- **Grid Nominal Voltage:** Voltage at the Point Of Interconnection (POI)

Single converter power parameters

- **Rated power:** Rated power of a single STATCOM converter.
- **Nominal AC voltage:** STATCOM converter Nominal Voltage. Voltage on the step-up transformer primary.

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- **Nominal DC voltage:** Nominal voltage on the DC side of the STATCOM
- **DC link capacitance**
- **Choke inductance:** Choke inductance. The choke is connected between the converter and the filter, on the STATCOM side of the step-up transformer (see Figure 1).
- **Choke resistance:** Choke resistance. The choke is connected between the converter and the filter, on the STATCOM side of the step-up transformer (see Figure 1).

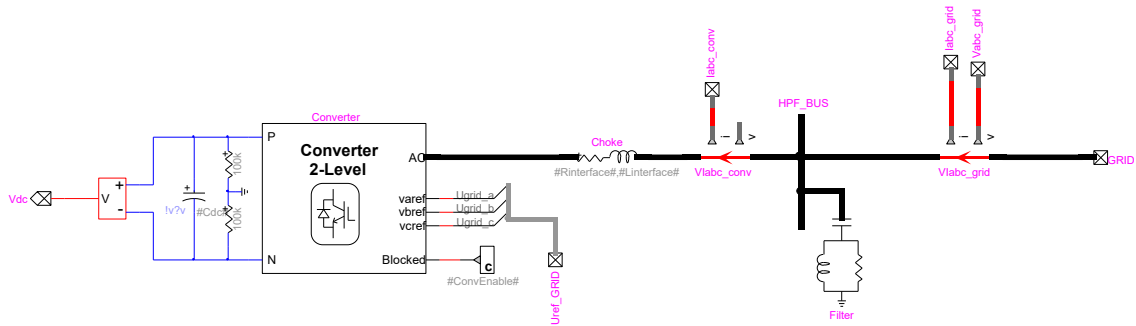


Figure 1: STATCOM 2-level converter

- **Filter rated power:** STATCOM high pass filter rated power (see Figure 2)

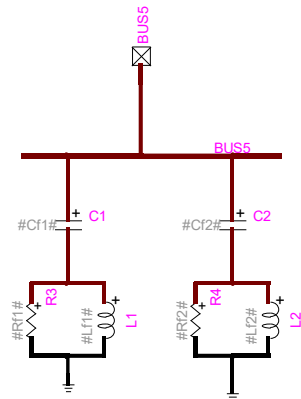


Figure 2: STATCOM filter

Operation conditions

- **Operation Mode:** STATCOM Q-control operating mode:
 - Q-control
 - V-control
 - Iq-control

In Iq-control is used when the STATCOM is part of a plant, for example a PV or a wind-park and the Q-control is performed by a power plant controller (PPC). In this case, the q-axis current reference is provided as an input. In this case, an input port may be added to the STATCOM model to allow the connection between the PPC and the STATCOM (see Figure 3).

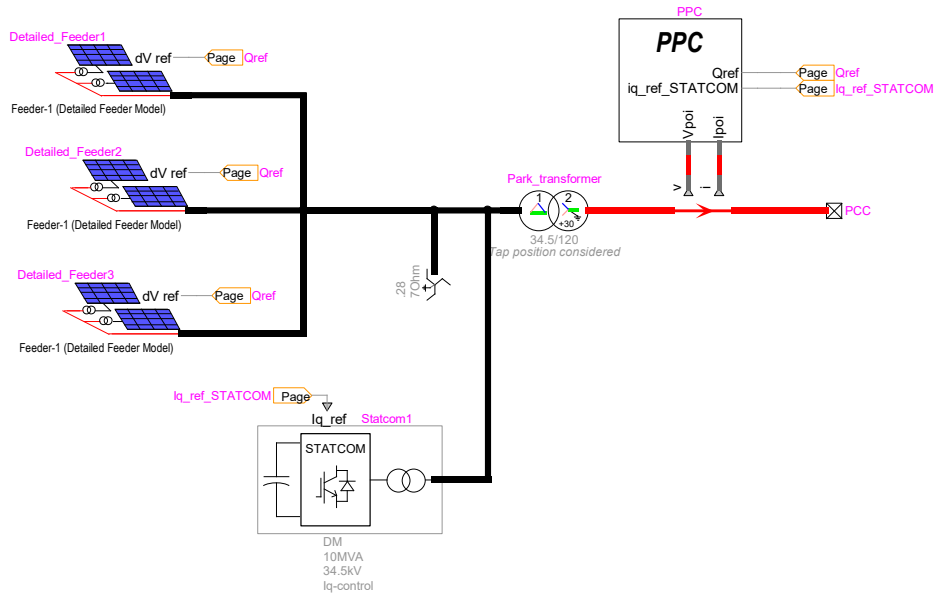


Figure 3: STATCOM in PV park, operating in Iq-control

- **Voltage reference:** Initial Voltage at point Of Interconnection.
- **Drop percentage:** Droop characteristic is given in %
- **Initial reactive power:** When Q-control is selected, this is the reactive power reference of the PV park controller.
For other control types, this is the initial reactive power at point Of Interconnection
- **Adjust the Initial reactive power input with the LF results:** If this box is checked, the Initial reactive power input is adjusted based on the reactive power of the PV park during load-flow condition. The value is adjusted once the user clicks on the OK button and any time a new simulation is run.

1.1.2 Transformer

See transformer documentation.

1.1.3 Control Converter

- **Converter model:**
 - DM: 2-Level Detailed converter model with IGBTs.
 - AVM: Average Value converter Model, no IGBTs.
- **PWM frequency:** PWM frequency of the Grid-side controller
- **Vpcc Ti:** time constant of voltage measurement at PCC
- **Qpcc Ti:** time constant of power measurement at PCC
- **Vref rate of change limit:** Rate of change limit of reference voltage.
- **Qref rate of change limit:** Rate of change limit of reference reactive power
- **Current limit:** Converter control current limit (normal operation).
- **d-axis Current limit:** Converter control d-axis current limit (during normal operation).
- **q-axis Current limit:** Converter control q-axis current limit (during normal operation).

- **Control dynamic input:** Select if control loops gains or time-constants are used as inputs. If time-constants is selected, gains are calculated using internal control theory (see [1])
- **Inner loop gains K_i , K_p**
- **Inner loop time-constant T_i :** used to calculate inner loop gain
- **DC voltage control (outer loop) gains K_i , K_p**
- **DC voltage control (outer loop) time-constant:** used to calculate outer loop gain
- **V-control (outer loop) gains K_i , K_p**
- **V-control (outer loop) time-constant:** Time constant of the closed-loop voltage control response to a step-change. Used to calculate outer loop gains for V-mode.
- **Q-control (outer loop) gains K_i , K_p**
- **Q-control (outer loop) time-constant:** Time constant of the closed-loop reactive power control response to a step-change. Used to calculate outer loop gains for Q-mode.

1.2 Reactive Power Control

The STATCOM reactive power control structure is based on dq0 (vector control) and consists of a 2-level control with a slower outer loop and a faster inner loop.

1.2.1 Outer loops

The d-axis outer loop regulates the DC voltage to its nominal value and creates the d-axis current reference of the inner loop to achieve this (see Figure 4).

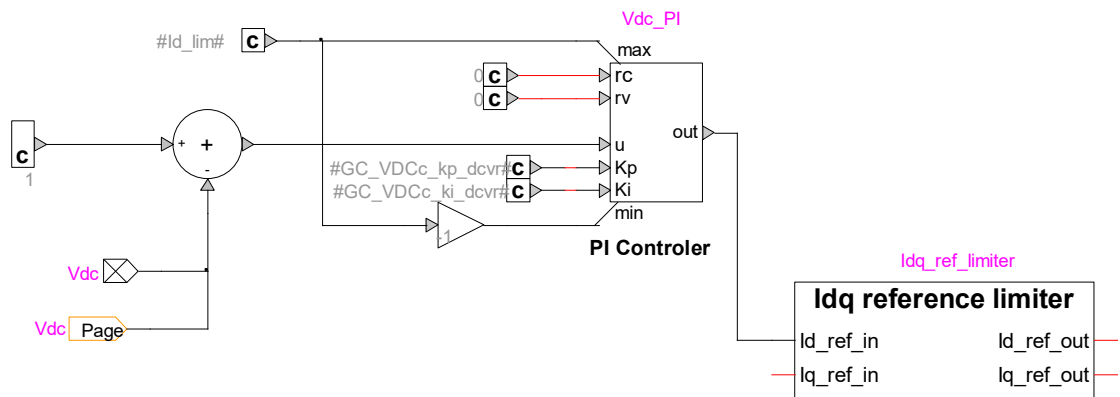


Figure 4: d-axis outer loop control (DC voltage regulation) in Statcom_Ctrl subcircuit.

The q-axis outer loop regulates the reactive power using either a voltage regulation (V-control), a reactive power regulation (Q-control) or a q-axis current control. In this last case, there is no q-axis outer loop and the q-axis current reference is the input of the inner loop.

Proportional Integral (PI) regulators are used. The output command of these loops is the q-axis current reference (see Figure 5). In V-control mode, a droop based on measured q-axis current is utilized [2].

The input reference variations of the q-axis outer loop controls are limited by rate limiters.

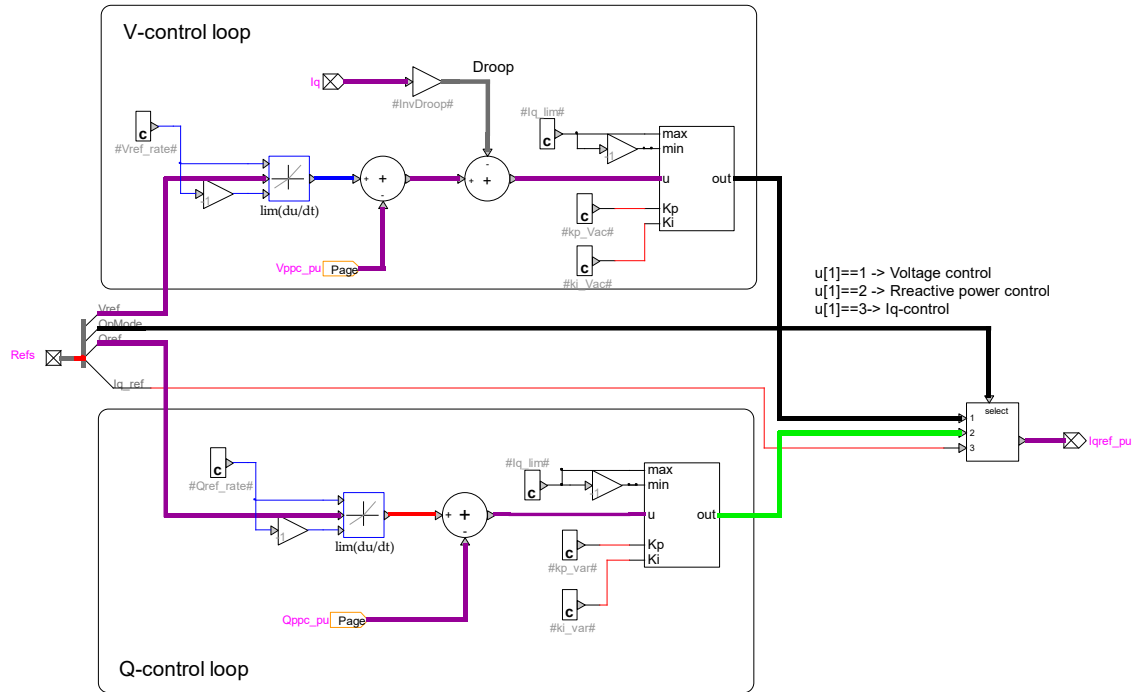


Figure 5: q-axis outer loop control (Reactive power regulation) in StatcomPCCcontrol subcircuit.

1.2.2 Inner loops

The references of the inner loops are the output commands (d-axis and q-axis current references) of the outer loops on which a limiter is applied (see 1.2.3).

The d-axis inner loop controls the d-axis voltage of the converter to follow the d-axis current reference.

The q-axis inner loop controls the q-axis voltage of the converter to follow the q-axis current reference.

A feedforward compensation is done for both loops (see Figure 6) to take into account the choke reactance.

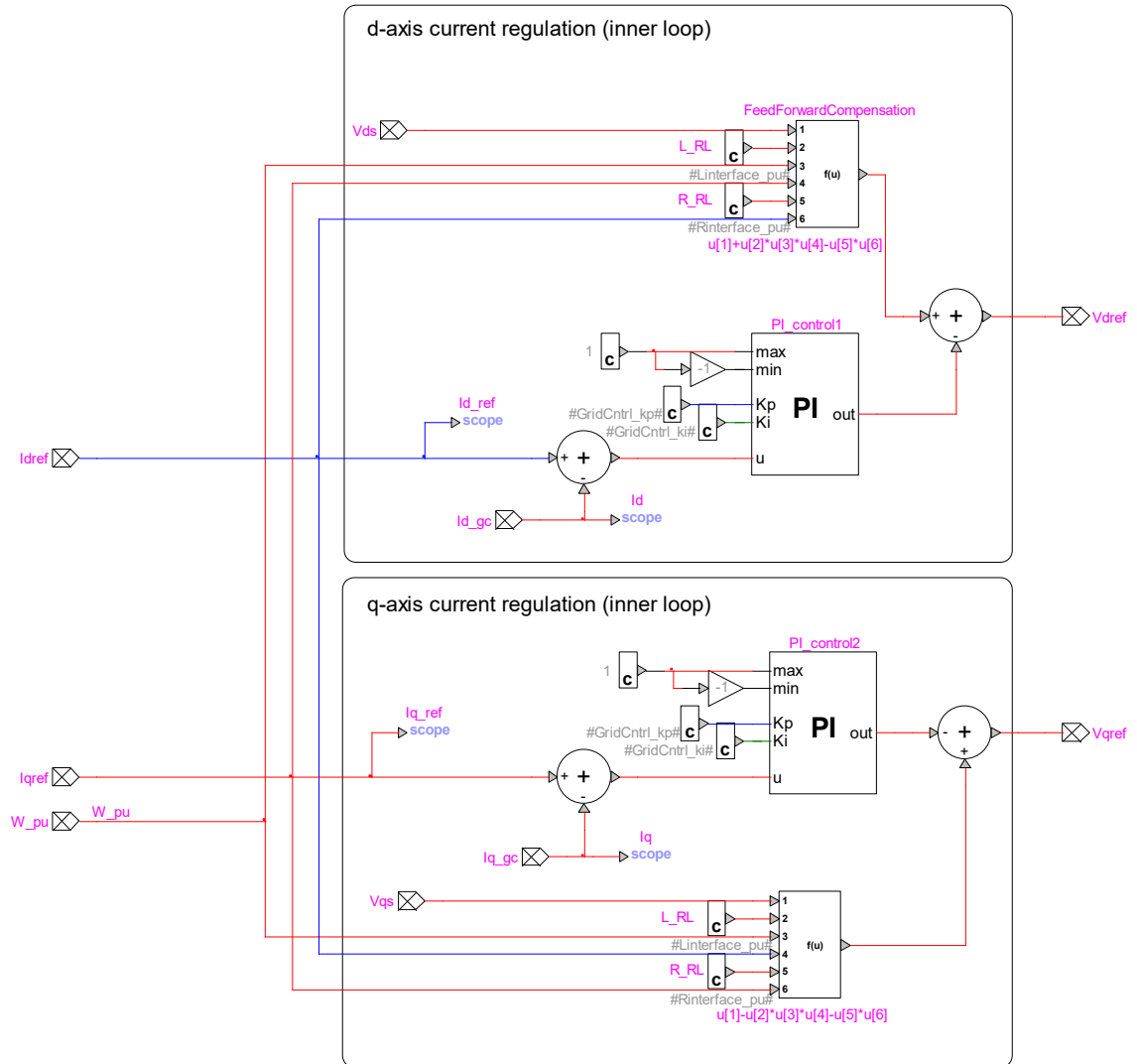


Figure 6: inner loop regulation

1.2.3 Current limiters

Current references from the outer loops are limited in magnitude of the total current and on both axis.

1.3 Phase Lock Loop (PLL)

The sampled signals input of the STATCOM controller are converted to per unit and filtered. The input measuring filters are low-pass (LP) type.

The controller operated in DQ0 reference frame where the reference is the grid-side voltage. The following PLL is used to track frequency and angle:

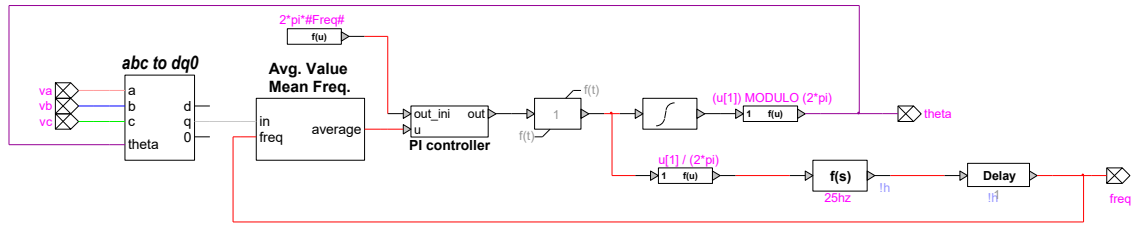


Figure 7: PLL

1.3.1 PV harmonic model

For harmonic analysis, the PV park is modeled with a harmonic Norton source. The harmonic study can be done in time domain, in which case **Use harmonic model for steady-state and time-domain simulations** must be checked or in the frequency domain with the frequency-scan simulation option, in which case **Use harmonic model for frequency-scan simulations**.

The harmonic currents are provided in percentage of the fundamental, for one inverter. The total park current is rescaled according to the number of inverters in service.

It is possible to automatically adjust the fundamental frequency current generated by each inverter and the harmonic current angles to match the load-flow results by checking **Adjust fundamental frequency current to match Load-Flow results**. When this box is checked, the **I Angle** input of the first line, which corresponds to the fundamental frequency current is adjusted to match the inverter current angle during the load-flow. The **Fundamental frequency current magnitude** is also adjusted to match the load-flow results. The fundamental frequency angle value is also added to the **I Angle** values of the other harmonics. Therefore, when this option is checked, the phase difference between the harmonic currents and the fundamental frequency current should be entered in the **I Angle** column.

2 References

- [1] L. Harnefors and H. Nee, "Model-based current control of ac machines using the internal model control", IEEE Trans on Ind. Appl., pp. 133-141, Jan/Feb. 1998.
- [2] N. G. Hingorani, L. Gyugyi, "Understanding FACTS; Concepts and Technology of Flexible AC Transmission Systems," IEEE Press book, 2000.