

PLECS

DEMO MODEL

Neutral-Point Clamped Converter

Last updated in PLECS 4.3.1

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1 Overview

This demonstration illustrates a neutral-point clamped (NPC), three-level voltage-source inverter. The NPC topology has been adopted for high power applications as it can achieve better harmonic reduction than traditional two-level voltage source inverters and the associated control strategies help to minimize semiconductor losses. This model is designed to deliver power to a 50 Hz, 130 V_{RMS} grid from a dynamic DC source.

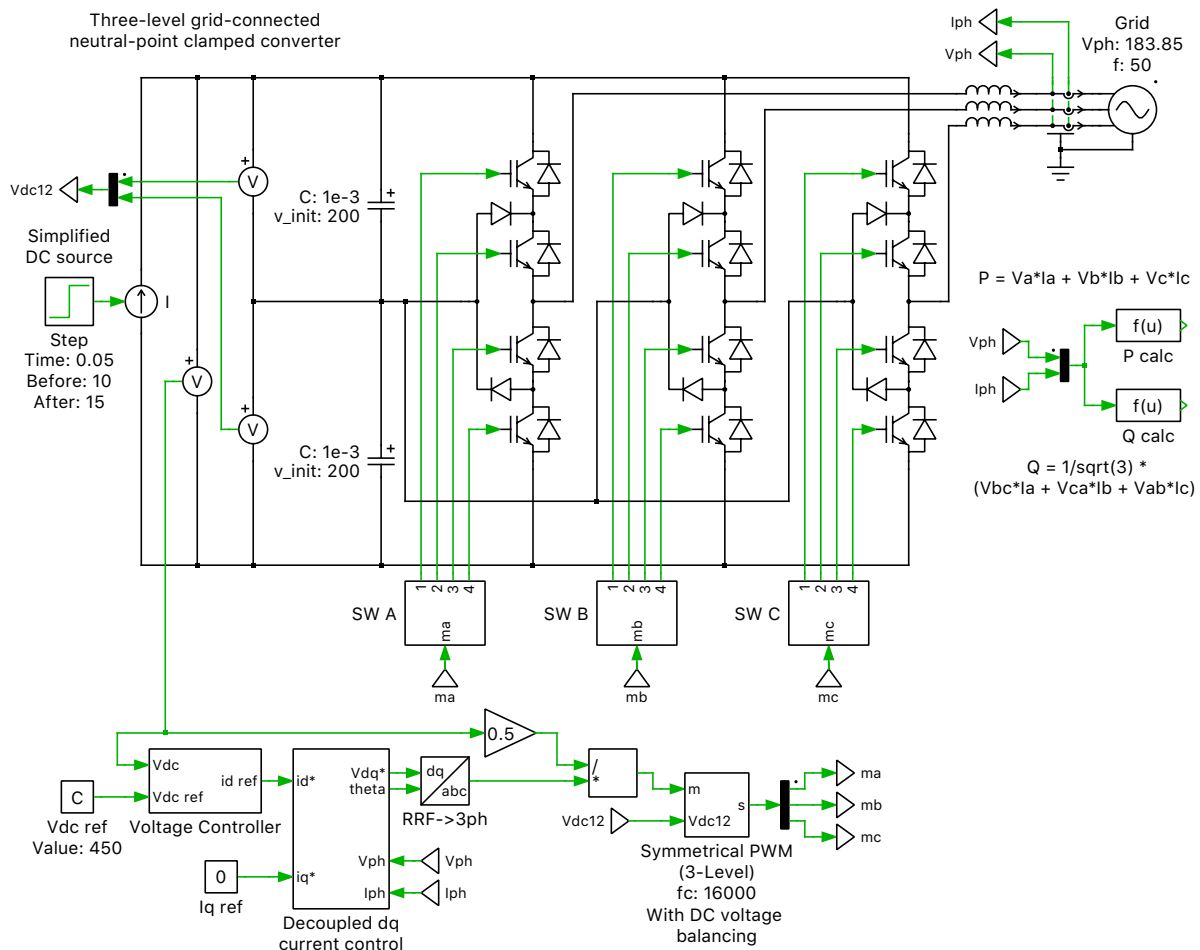


Figure 1: Neutral-point clamped converter

2 Model

2.1 Power Circuit

The circuit model is a bidirectional three-level voltage-source inverter (VSI), with three legs, one per phase, each containing two series-connected high-side switches and two series-connected low-side switches. Often, IGBTs with anti-parallel diodes are used as the switches for an NPC converter, but other two-quadrant switch configurations can also be employed. In this case, the IGBT 3-Level Half Bridge power module components are used, which each implement a single leg for an NPC converter. The power module has two configurations: a switched configuration where ideal switches represent the semiconductors, and an averaged configuration that uses controlled voltage and current sources. The averaged configuration is particularly well suited for real-time simulations with high switching frequencies, such as for hardware-in-the-loop testing.

The DC source, e.g., photovoltaic panels feeding a solar inverter, is modeled as a controlled current source. It provides $10 A_{DC}$ for the first half of the simulation and $15 A_{DC}$ for the second half of the simulation, corresponding to a sudden increase in received solar energy. This current charges the DC bus, which is split into two series-connected capacitors, with the mid-point connected to each of the three IGBT legs. Clamping diodes are placed between the capacitor mid-point and the one-quarter and three-quarter points of each leg. The mid-point of each leg is then fed to the respective phase of the AC grid via an inductor. The grid is modeled as an ideal three-phase 50 Hz, $130 V_{RMS}$ voltage source. The DC capacitors have initial voltages of $200 V_{DC}$, though the setpoint for the DC bus is $450 V_{DC}$, so they will charge up at the start of the simulation.

2.2 Controls

An outer voltage controller implemented as a PI regulator provides a current setpoint to an inner dq current controller. The voltage controller measures the DC voltage and calculates the error compared to the $450 V_{DC}$ reference value. The current controller has separate PI regulators for direct and quadrature currents that produce a V_{dq} reference. The AC phase voltages and currents are measured and fed to the current controller. A Phase-Locked Loop (PLL) generates the reference phase angle for the abc to dq transformations. A low pass filter is inserted into the feedback path from the $I_{a,b,c}$ measurement to represent the limited bandwidth of the current sensor. Modulation indices are generated for each of the three separate modulators for the three phase legs.

3 Simulation

Run the simulation with the model as provided to view the signals and observe that the DC voltage is regulated to $450 V_{DC}$ after the transients settle. The perturbation caused by the step change in current from the PV array is regulated out in approximately 50 ms. The switching pattern clearly shows a three-level pulse train with the fundamental waveforms phase-shifted. The real and reactive power delivered to the grid can also be observed.

Revision History:

PLECS 4.3.1 First release

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PLECS Demo Model

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