



PLECS

*DEMO MODEL*

## Single-Phase PV Inverter

Last updated in PLECS 4.3.1

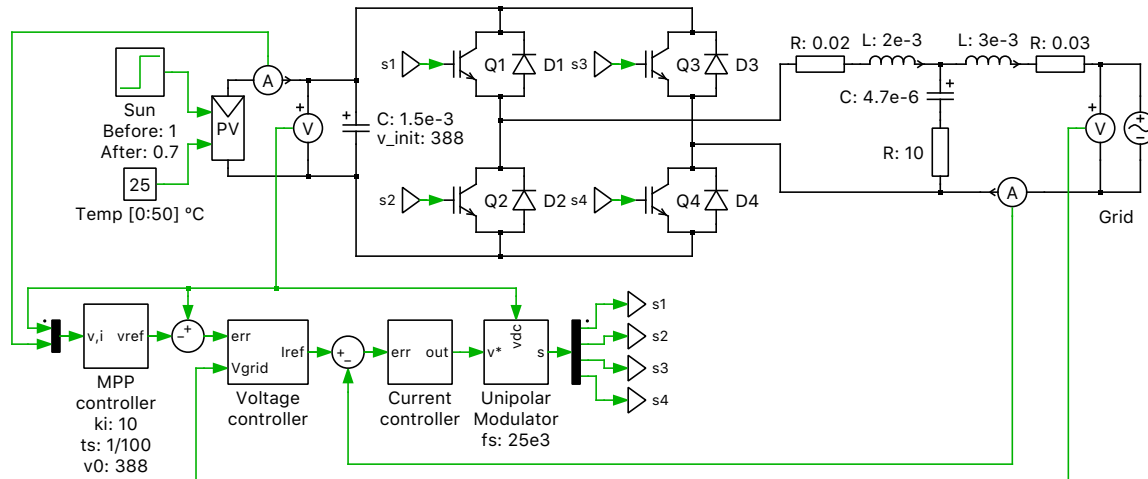
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# 1 Overview

Single-phase PV inverters are commonly used in residential rooftop PV systems. In this application example, a single-phase, single-stage, grid-connected PV inverter is modeled. The PV system includes an accurate PV string model that has a peak output power of 3 kW.

## 2 Model



**Figure 1: Inverter system**

The power generation system is comprised of a solar array that provides a steady-state output of approximately 380 VDC, an IGBT-based full bridge inverter, and an LCL output filter connected to a 230 V<sub>rms</sub>, 50 Hz single-phase mains.

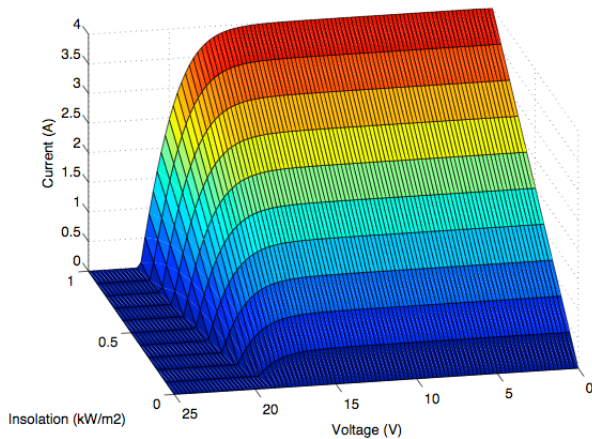
### 2.1 PV String Model

The PV string component is based on a non-linear current source that accurately models the IV characteristic with variable inputs of insolation (sun intensity), output voltage, and temperature. Further, it can be connected in various series and parallel configurations and used as a DC source for both of-line and grid-connected systems. The model is based on the Shockley diode equations for accuracy and can be used to study the interactions between a PV inverter and the supply modules. The typical output current characteristic of the PV model is shown in Fig. 2.

In this example, insolation and temperature-dependent data has been mapped for a BP365 65 W solar module, and the array comprises 22 modules connected in each string, with 2 strings connected in parallel. The current surface data, is saved in a .mat file and contains information for the characteristic IV curves for an insolation range of 0 to 1 kWhr/m<sup>2</sup>, voltage values between 0 and 25 V, and three temperatures of 0, 25, and 50 °C.

### 2.2 Control

The control system comprises three control loops: a maximum power point (MPP) controller, a voltage controller and a current controller. These can be seen in the circuit diagram in Fig. 1. The outer control loop is a MPP controller that ensures maximum power is extracted from the PV string for a given insolation level. To do this, it calculates the optimal PV terminal voltage using a MPP algorithm known as dP/dV (incremental conductance) control, implemented using a C-Script block. The voltage control loop, based on a type 2 controller, regulates the PV voltage to this optimal level by controlling



**Figure 2: Typical output current characteristic of the BP365 PV module model at 25 °C.**

the amount of current that is injected into the grid. The innermost control loop, the current controller, sets the modulation index of the inverter such that the desired current is injected into the grid. The current controller is based on a PR controller with a resonant frequency of 50 Hz to ensure no tracking error is present. Finally, a unipolar modulation scheme is deployed with a switching frequency of 25 kHz. Also, a damping resistor is included in the LCL output filter to ensure stable operation of the current controller.

### 3 Simulation

The simulation shows output of the array and inverter at startup conditions and as the system settles to steady-state conditions over 4 s. The first Scope shows the sinusoidal mains voltage, injected sinusoidal grid current, and resulting power produced onto the grid. A second Scope shows the voltage, current, and power resulting from the PV array. An XY Plot provides the power vs. voltage characteristic and the MPP controller's influence on the output power from the array.

At simulation start, the DC bus capacitor is pre-charged to 388 V resulting in minimal startup transient behavior. A nominal value of 1 kWhr/m<sup>2</sup> for the sun insolation is provided. At  $t = 2$  s, a reduction in the insolation level to 0.7 kWhr/m<sup>2</sup> is experienced, and the XY plot shows that a new MPP is achieved.

The user can manipulate the sun insolation level, temperature, as well as array scaling characteristics, and also include their own IV current surface data for the PV module building block.

## Revision History:

PLECS 4.3.1      First release

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