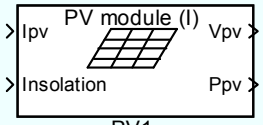
PV Module
Simulink models

ECEN 2060

Spring 2008

Simulink models of PV modules

Current-input PV module



Inputs:

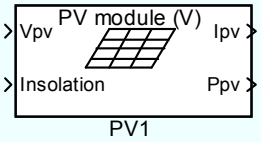
- PV current I_{PV} [A]
- Insolation [W/m^2]

Outputs:

- PV voltage V_{PV} [V]
- PV output power Ppv [W]

This model is well suited for the case when modules are connected in series and share the same current

Voltage input PV module



Inputs:

- PV voltage V_{PV} [V]
- Insolation [W/m^2]

Outputs:

- PV current I_{PV} [A]
- PV output power Ppv [W]

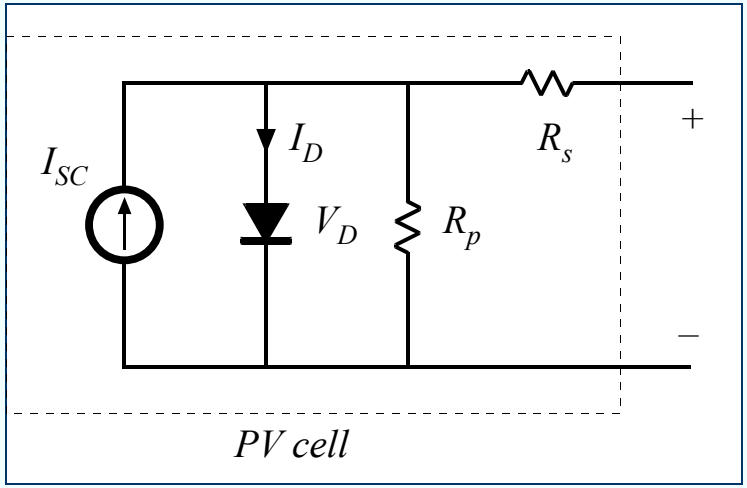
This model is well suited for the case when modules are connected in parallel and share the same voltage

Model parameters, in both cases, are the standard PV module data-sheet parameters:

- short-circuit current I_{sc}
- open-circuit voltage V_{oc}
- rated current I_R at maximum power point (MPP)
- rated voltage V_R at MPP

under standard test conditions (1kW/m^2, 1.5 AM, 25^{o}C). A bypass diode (a single diode across the entire module) can be included. Temperature effects are not modeled.

PV cell circuit model and equations



KCL:

$$I_{SC} - I_D - \frac{V_D}{R_p} - I_{PV} = 0$$

Diode characteristic:

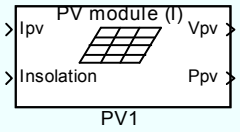
$$I_D = I_o\left(e^{V_D/V_T} - 1\right)$$

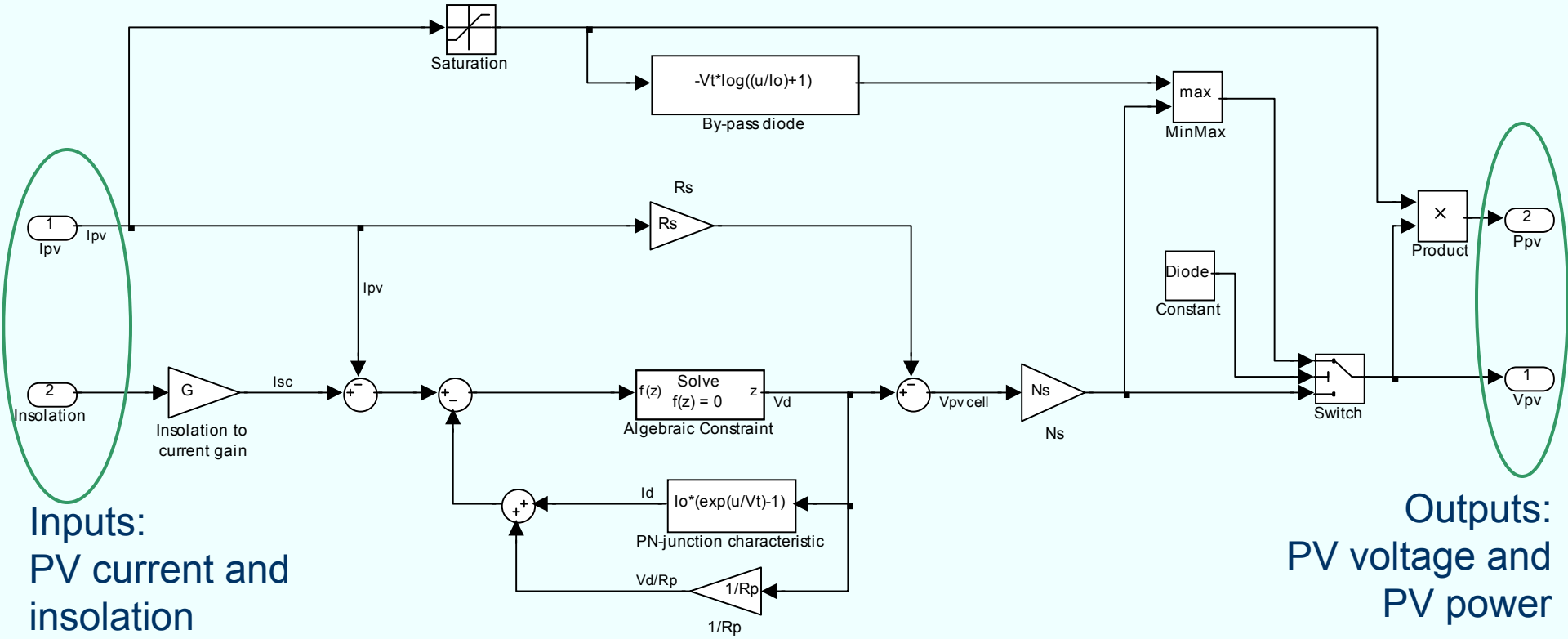
KVL:

$$V_{PVcell} = V_D - R_s I_{PV}$$

Simulink Implementation

- Both PV module models are implemented as masked subsystems in Simulink
- Look Under Mask (right-click or Edit menu) reveals details of the model implementation
- Details of the current-input PV module model:

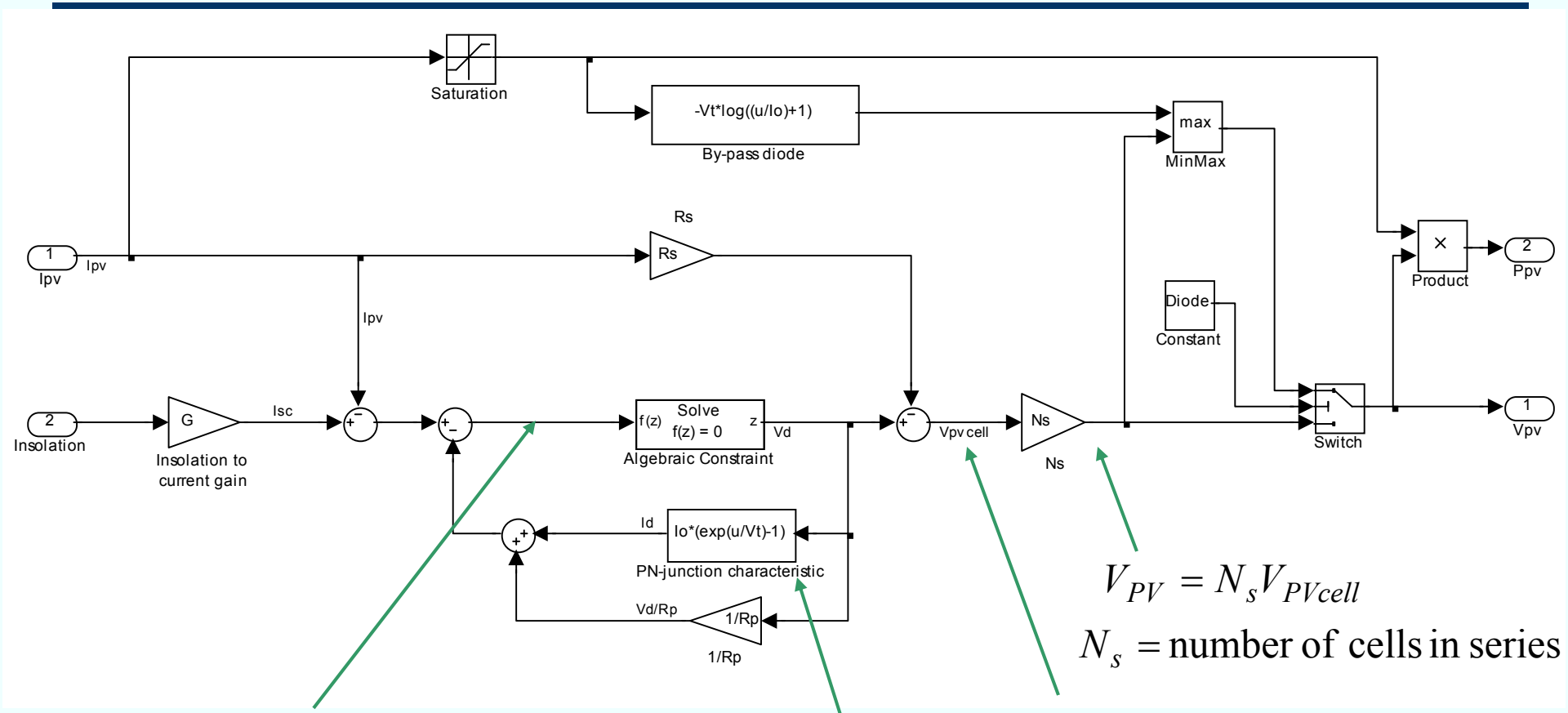




Inputs:
PV current and insolation

Outputs:
PV voltage and PV power

Inside the current-input PV module model



$$V_{PV} = N_s V_{PVcell}$$

N_s = number of cells in series

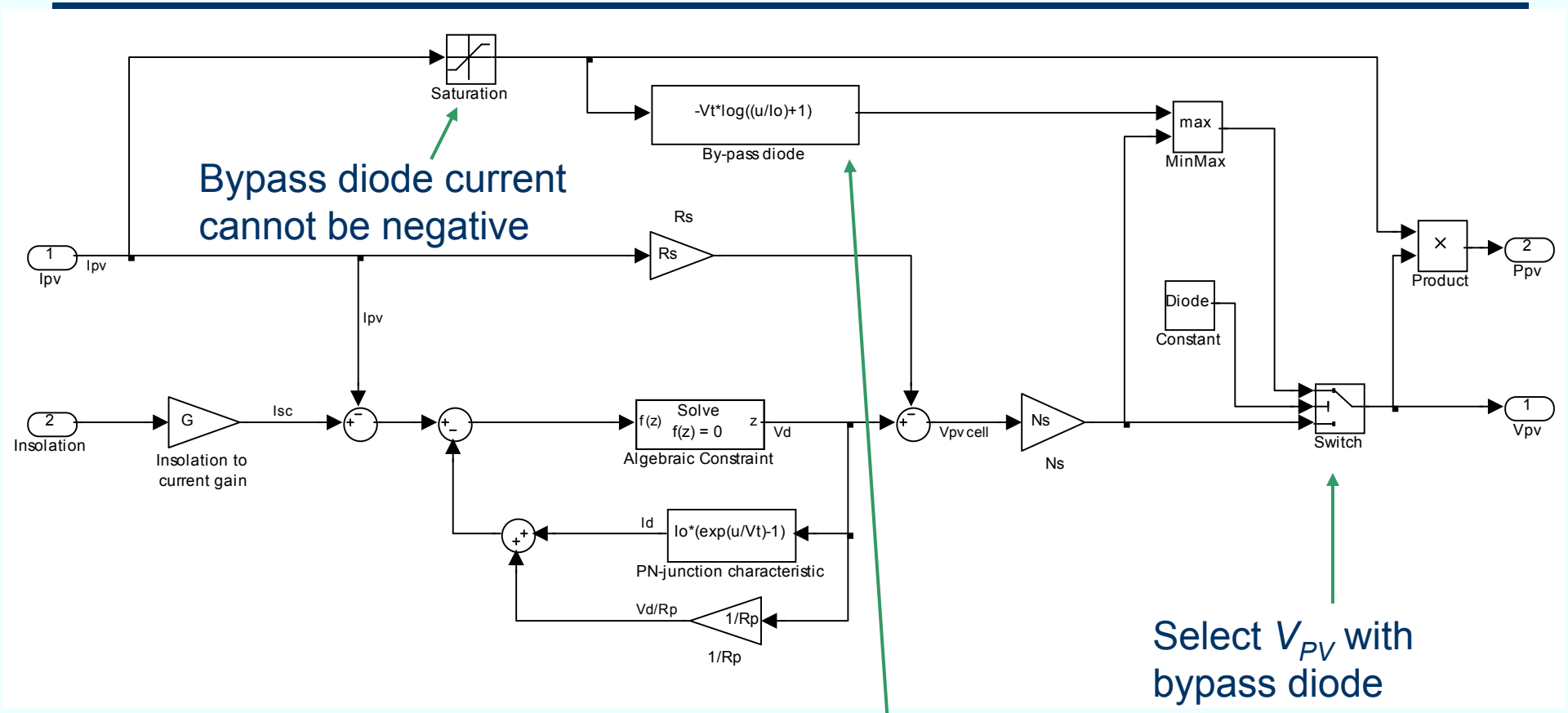
$$V_{PVcell} = V_D - R_S I_{PV}$$

$$I_{SC} - I_D - \frac{V_D}{R_p} - I_{PV} = 0$$

$$I_D = I_o\left(e^{V_D/V_T} - 1\right)$$

KCL solved for V_D using Algebraic Constraint block

Inside the current-input PV module model



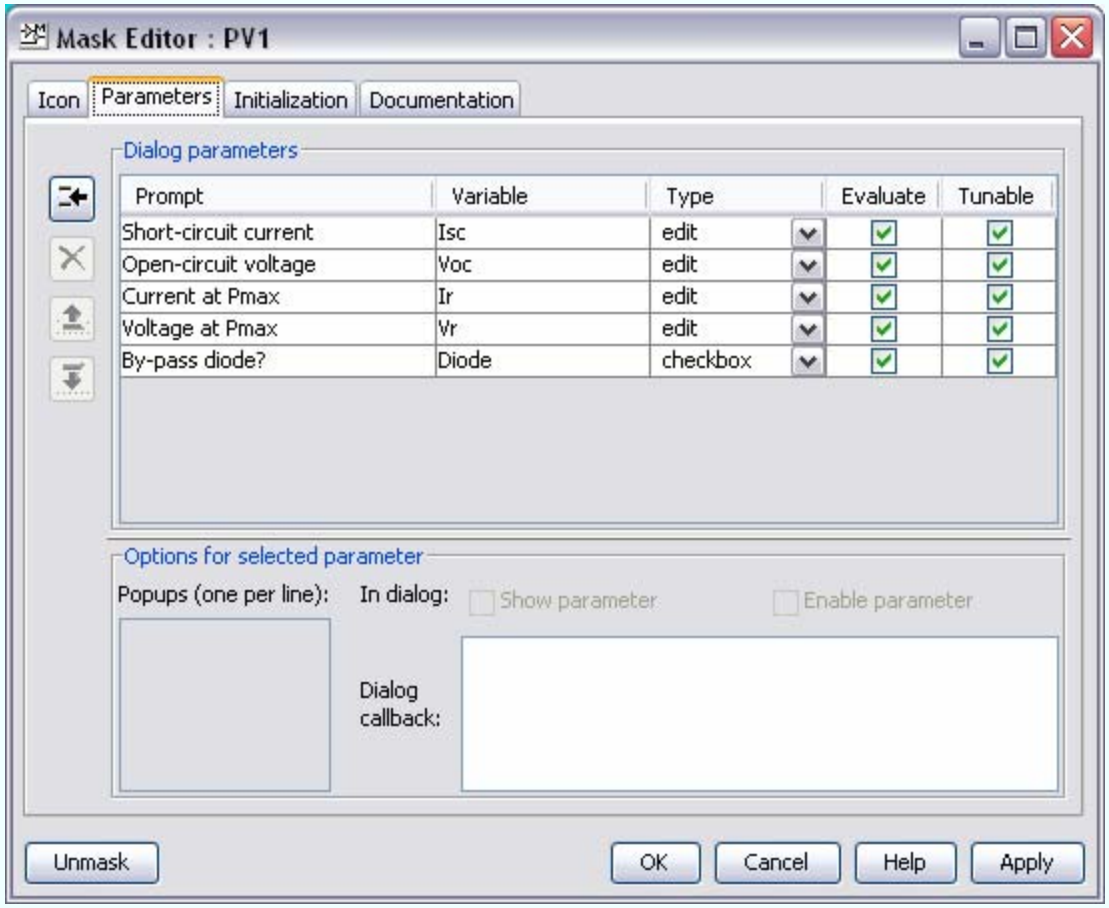
$$V_{Dbypass} = V_t \ln\left(\frac{I_{bypass}}{I_o} + 1\right)$$

Bypass diode voltage (if forward biased)

Select V_{PV} with bypass diode ("Diode" = 1) or without bypass diode ("Diode" =0)

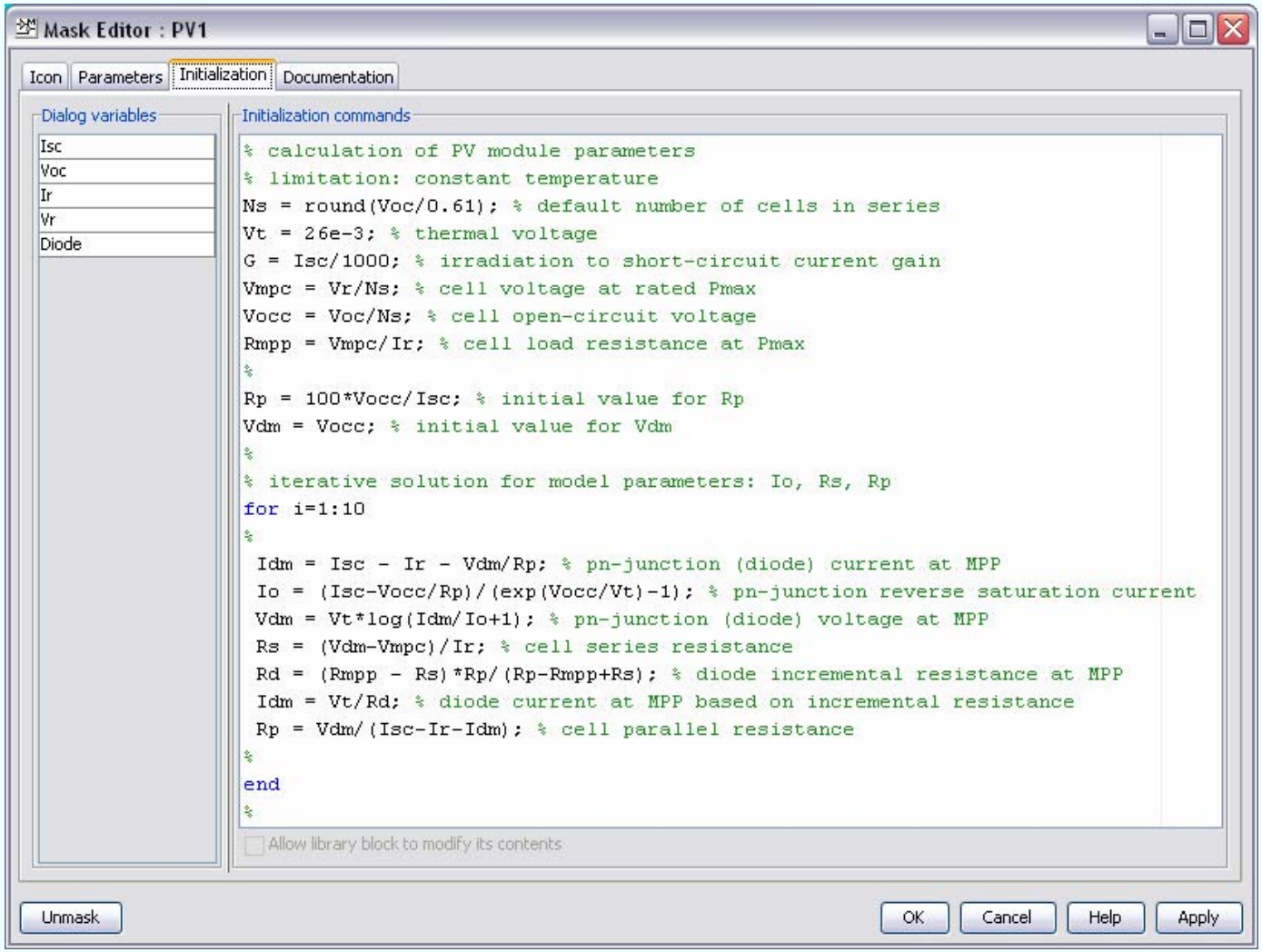
Model Mask: Parameters

- Edit Mask (right-click or Edit menu), click on Parameters
- This is where the masked subsystem model parameters are defined



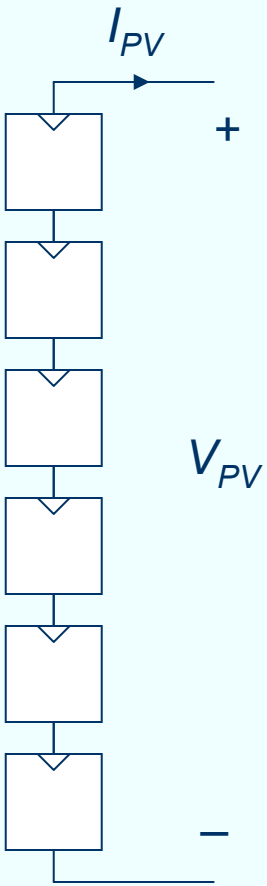
Model Mask: Initialization

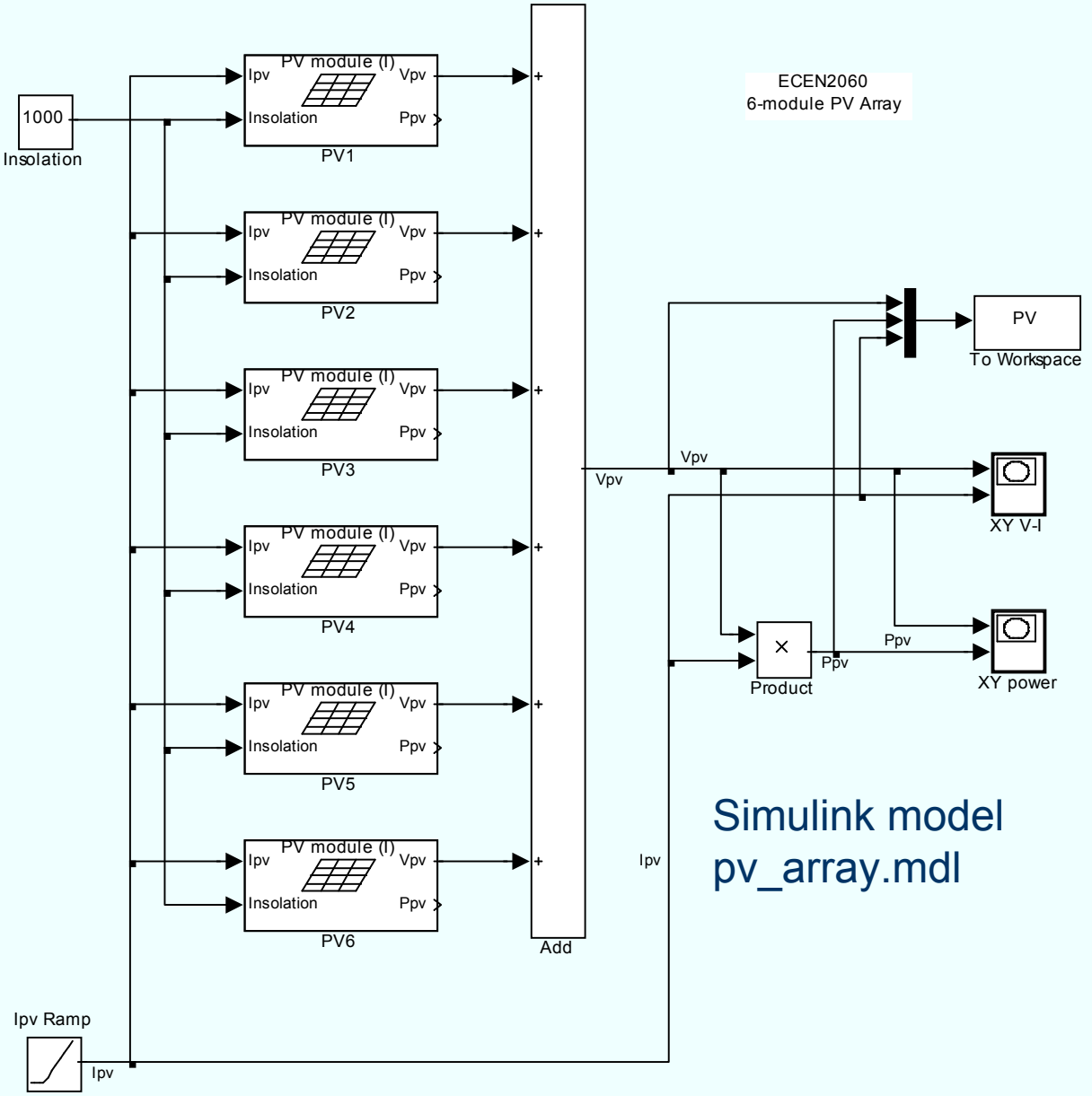
- Edit Mask (right-click or Edit menu), click on Initialization
- The MATLAB code computes model parameters I_o, R_s, R_p based on the model parameters (short-circuit current I_{sc}, circuit voltage V_{oc}, rated voltage V_r, and rated current I_r)



Application Example: PV Array

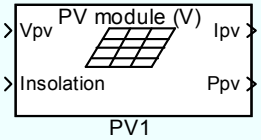
PV array consisting of 6 PV modules connected in series

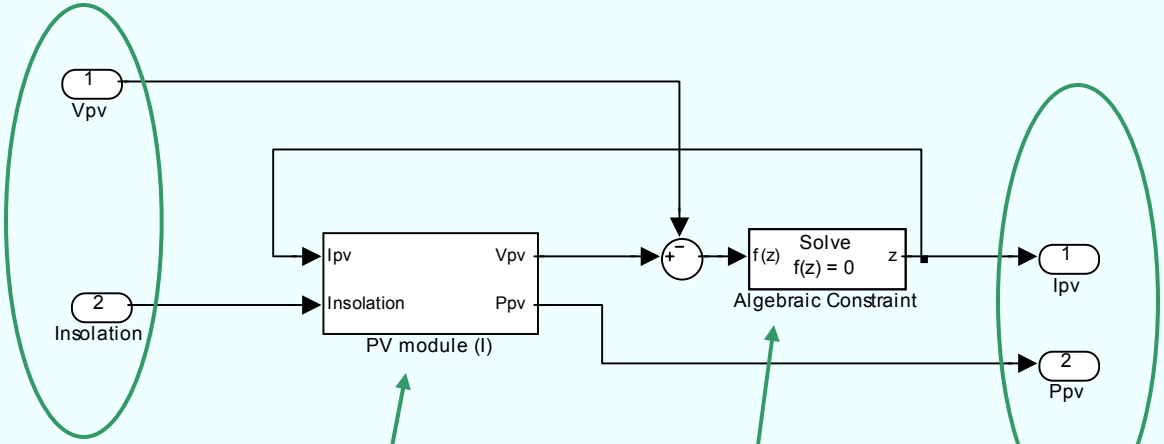




Simulink model pv_array.mdl

Inside the voltage-input PV module





Inputs:
PV voltage and insolation

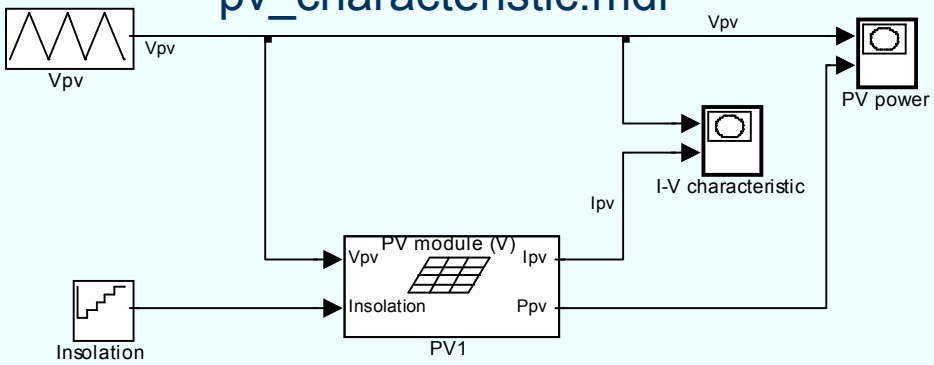
Current-input PV model

Algebraic Constraint block solves for I_{PV} that results in V_{PV}

Outputs:
PV voltage and PV power

Application Example: PV Module Characteristics

Simulink model:
pv_characteristic.mdl



Insolation = 200, 400, 600, 800, 1000 W/m^2