



# Photovoltaic Example

Written for PSCAD v4.6  
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Revision 1





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### 1. General description of the photovoltaic system

This document outlines the implementation of a PV system in PSCAD. Figure 1 shows the PSCAD main page of the photovoltaic (PV) system PV\_generic\_example.pscx. A general description of the entire system and the functionality of each module are given to explain how the system works and what parameters can be controlled by the system.

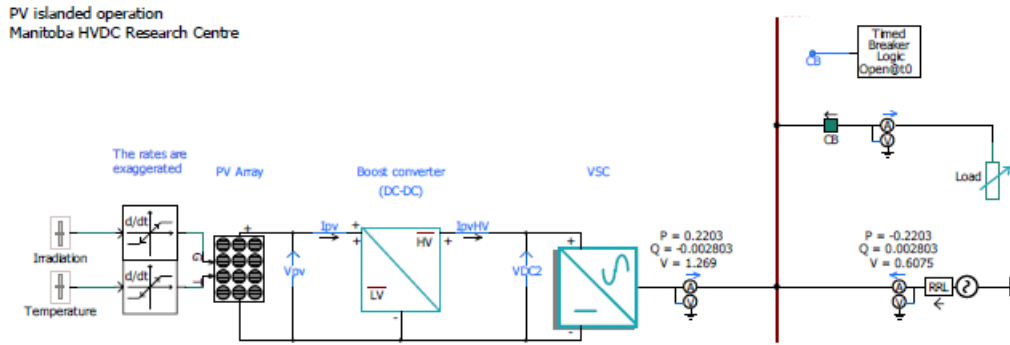


Figure 1: Overall PV system connected to a simple grid

The PV array is connected to a DC-DC converter (boost converter). The output power of the PV array is a function of the inputs namely irradiation and temperature.

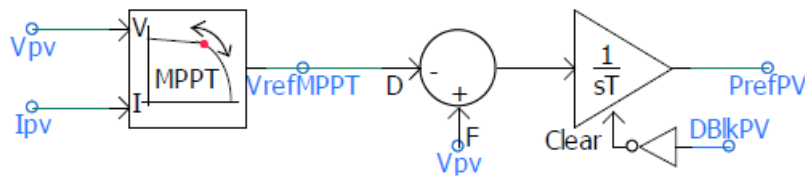


Figure 2: Maximum power point tracker and the reference power control system

Based on the reference power generated by the maximum power point tracker (MPPT) the boost converter adjusts the dc link current  $I_{pvHV}$  (see Figure 1). The voltage source converter (VSC) controls the dc voltage  $V_{DC2}$  and tries to maintain it its reference value.

For example, if the PV power increases because of an irradiation increase on the PV array, the boost converter increases its duty cycle so that more current is drawn from the PV array. As a result the dc link voltage  $V_{DC2}$  increases. To maintain the dc voltage level on the dc link the VSC draw more current from the dc link. Therefore regulating the dc link voltage and meeting the power reference from the MPPT.

More detailed description of the system is given in the following sections.

## 2. PV Array

The PSCAD example (PV\_Array\_Model.pscx) shows the characteristics of the PV array.

Figure 3 shows the circuit where the PV array is connected to a resistance.

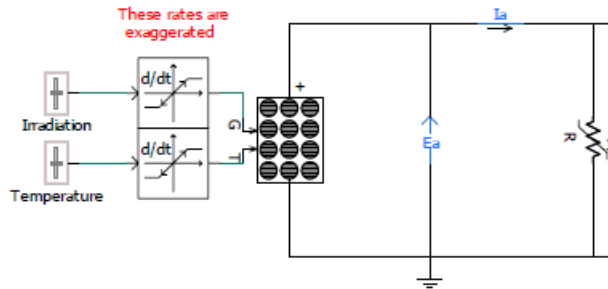


Figure 3: circuit setup to understand the characteristics of the PV array

Double click on the PV array to edit the parameters of the PV array and the PV cell as shown in Figure 4.

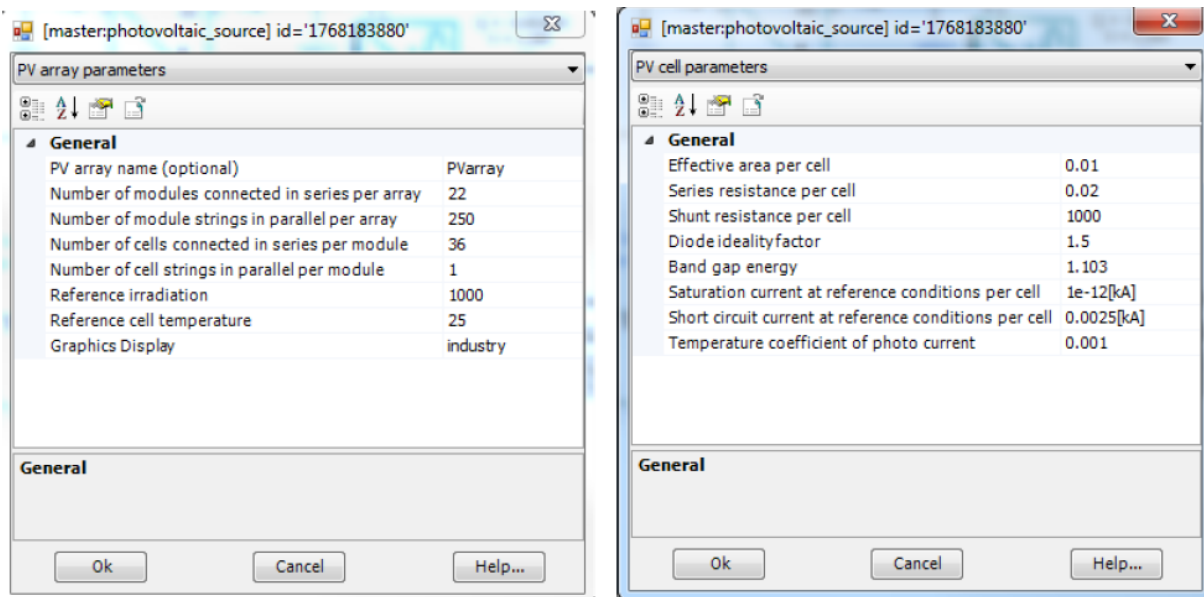


Figure 4: Parameters of the PV array and its cells

Figure 5 shows the variation of resistance (R) over time and the consequent variations of the terminal voltage  $E_a$  and current  $I_a$ . The reference voltage of the maximum power point tracker (MPPT) is also shown in Figure 5. As can be seen from the figure the  $V_{MPPT}$  is between 0.5 and 0.55 kV for this photovoltaic system.

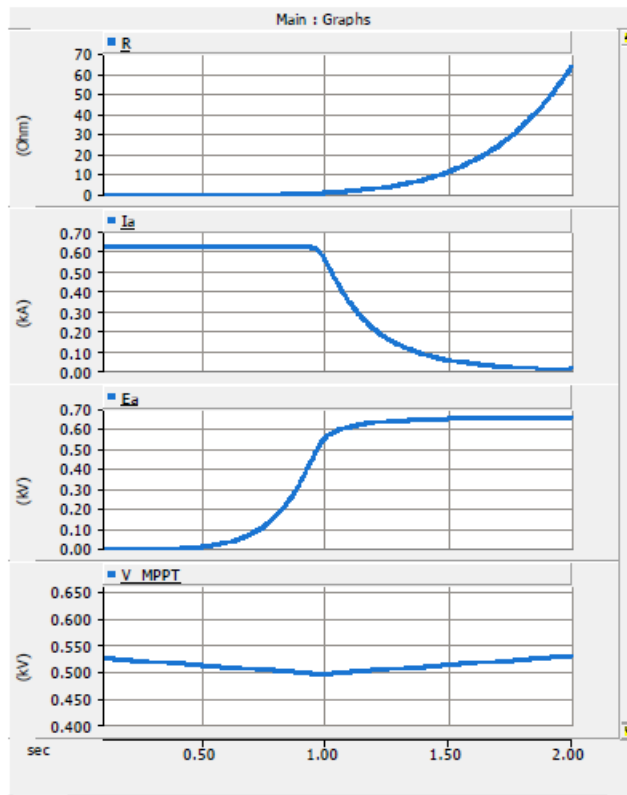


Figure 5: Variation of the resistance (R) in the circuit and the consequence variations in current and voltage.

The PV array characteristics such as V-I and P-V can be obtained. Ea (in kV) is plotted against Ia (in kA) in Figure 6 and Ea (in kV) is plotted against P (in MW) in Figure 7.

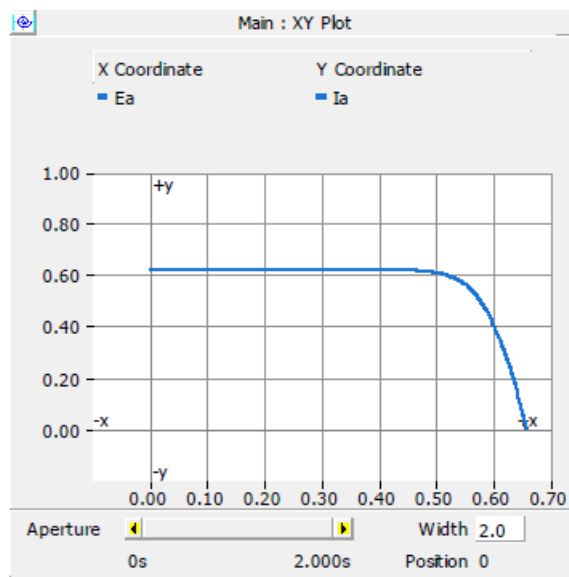


Figure 6: Variation of Ea (x axis ) vesuse Ia (y (vertical) axis )

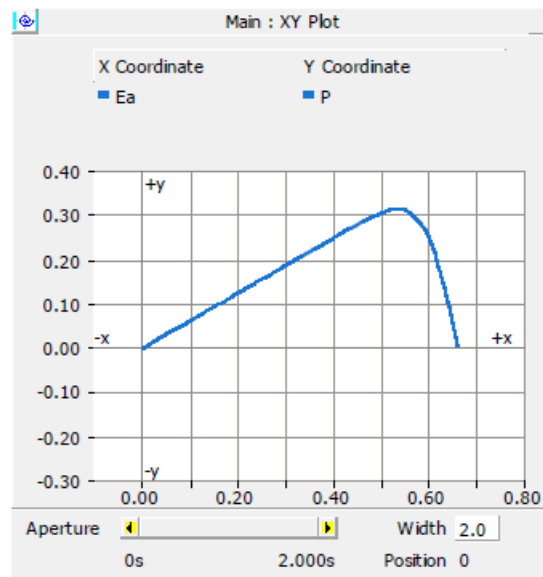


Figure 7: Variation of Ea (x axis ) vesuse P (y axis)

### 3. Boost converter

The boost converter shown in Figure 8 consists of a low pass filter at the input side. The controller is shown in Figure 9 where the reference power (Pref) is compared to the dc link power (Pdc) and the error signal is given to a PI controller to generate the boost converter duty cycle (Ref\_Boost). The PI controller coefficients (i.e. KpBoost and TiBoost) and its output limit (DmaxBoost) can be adjusted using the control panel shown in Figure 9.

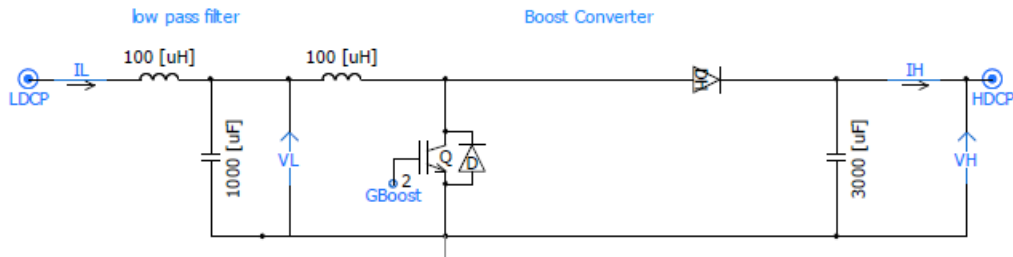


Figure 8: Boost converter

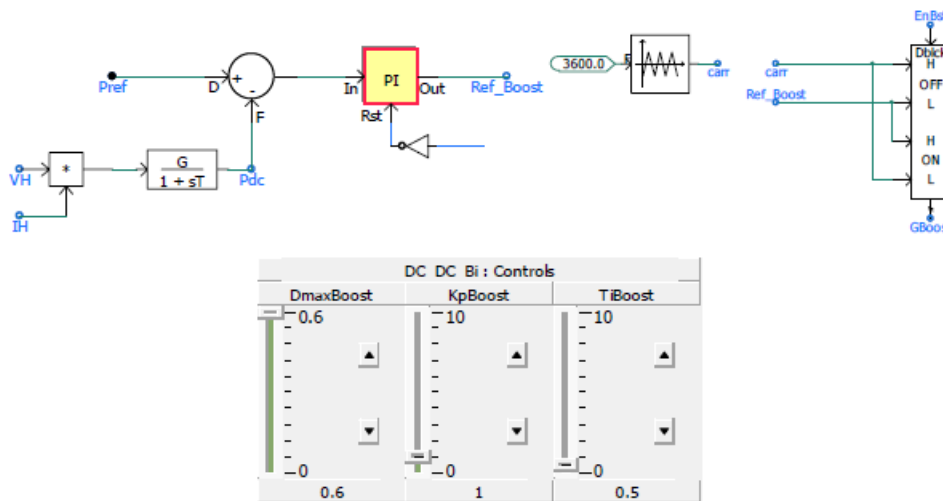
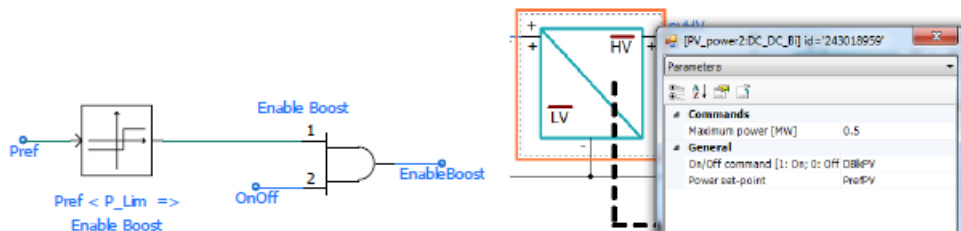


Figure 9: Power controller

To protect the boost converter against high currents the reference power is limited to a maximum power (P\_lim). To see the limit, right click on the boost converter component and select “Edit Parameters”. A window opens showing maximum power which is 0.5 MW in this example.



#### 4. Voltage source converter

To edit the parameters of the VSC, right click on the VSC component and select “Edit parameters”, see Figure 10. The reference reactive power is in MVar (Negative value indicates the VSC generates reactive power, and positive value indicates the VSC consumes reactive power).

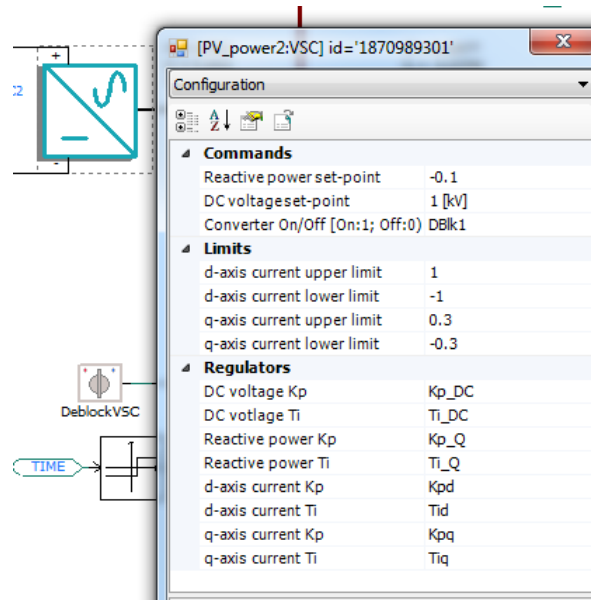


Figure 10: Voltage source converter module and the input parameters.

Figure 11 shows the coefficients for PI controls and the panels to modify the values if required.

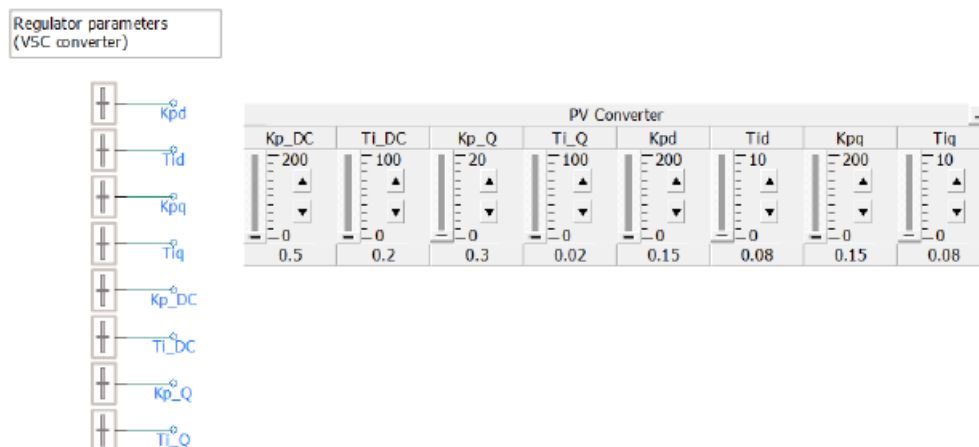


Figure 11: The Kp and Ti coefficients of the PI controllers for VSC



The power electronic circuit of the VSC converter is shown in Figure 12. The dc link capacitors are 3.9 mF.

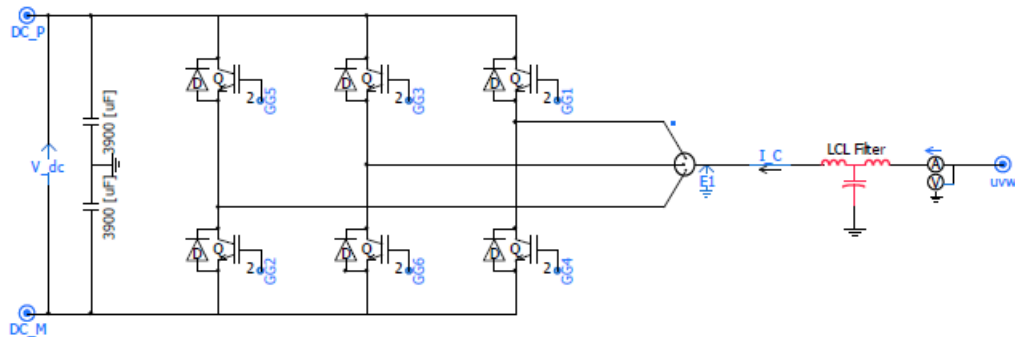


Figure 12: The voltage source converter the dc link capacitors and the ac side filter

The dc voltage controller is shown in Figure 13.

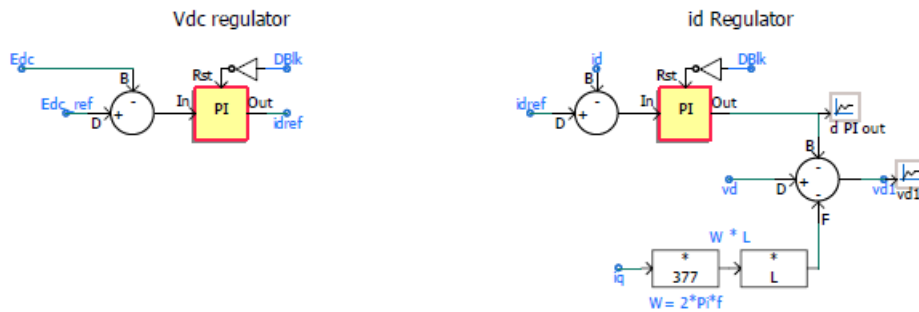


Figure 13: The dc voltage controller

The reactive power controller is shown in Figure 14.

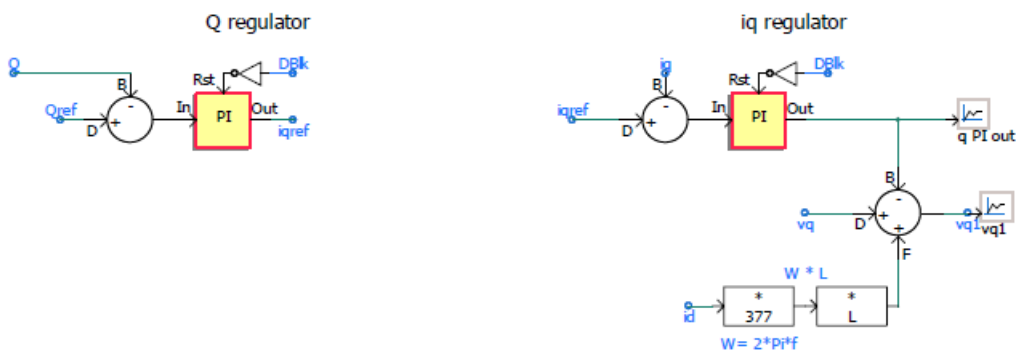


Figure 14: The reactive power controller

The dynamic of the system is shown in Figure 14 when a load connects to the system at 3.5 sec. When the load is connected to the system the PV system power  $P_{VSC}$  remains constant however the grid power  $P_{grid}$  varies accordingly.

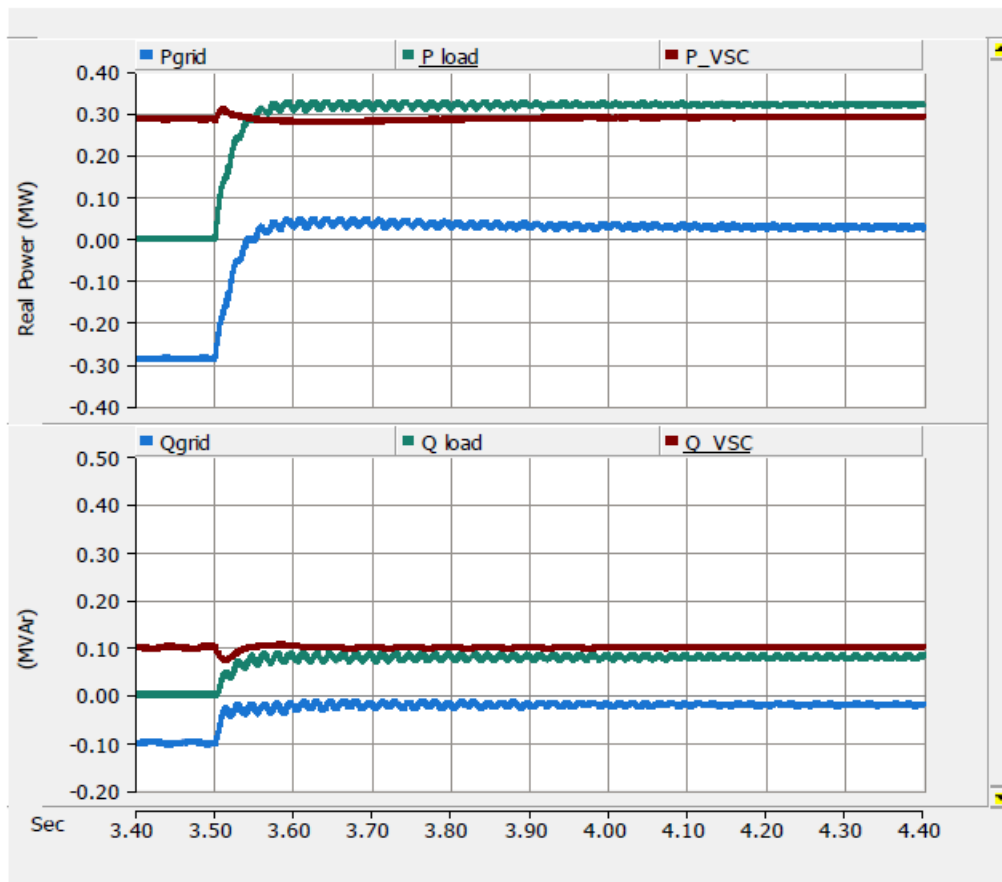


Figure 15: The dynamic of the system when the load is connected at 3.5 sec.

Irradiation decreases from 1200 W/m<sup>2</sup> to 800 W/m<sup>2</sup>. Therefore the power reference from the MPPT reduces and the dynamics are shown in Figure 16.

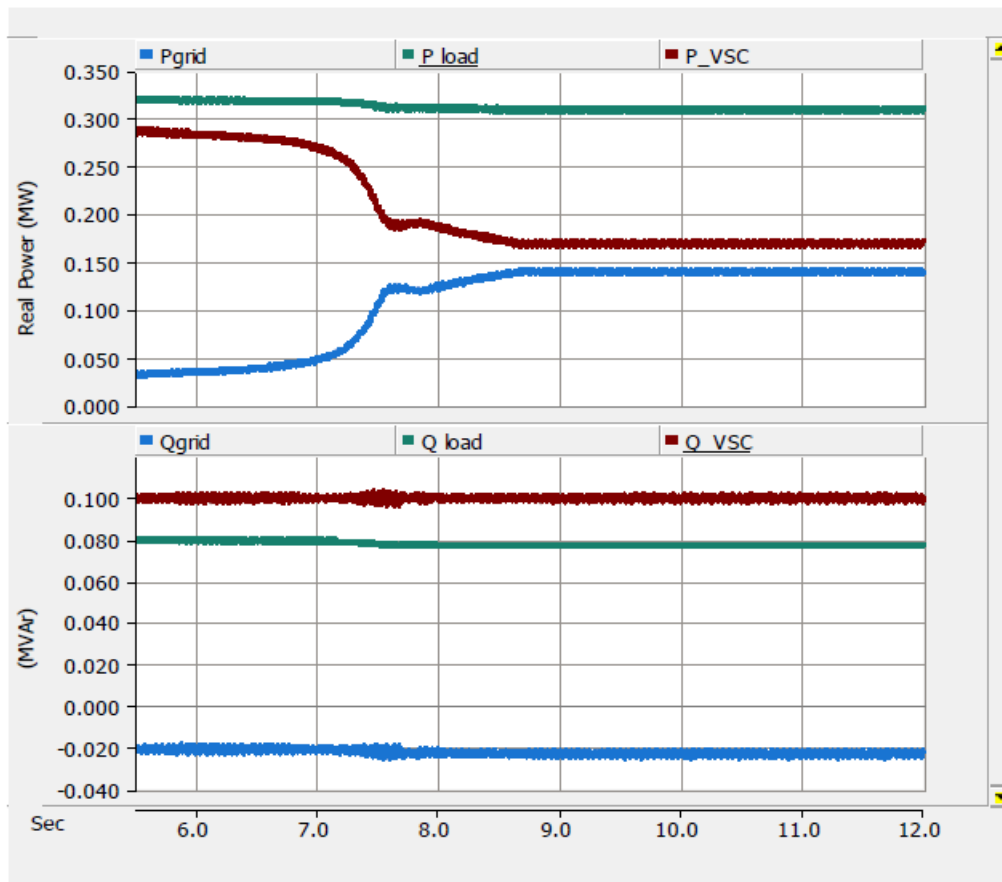


Figure 16: The dynamic of PV power as the irradiation reduces



DOCUMENT TRACKING

Rev.	Description	Date
0	Initial	12/Nov/2016
1	Updated to the new Branding Guidelines	25/Sep/2018