solar_shade_1.sqproj

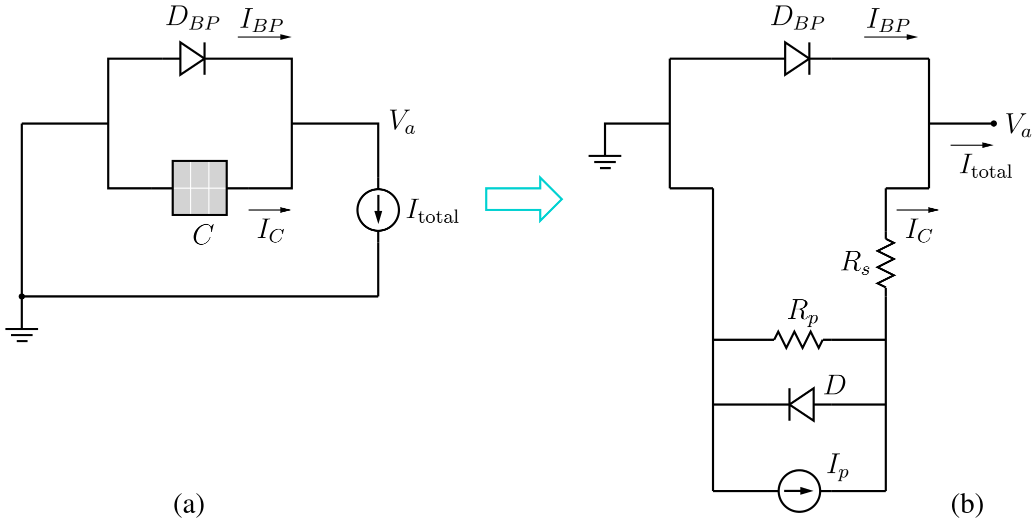

Figure 1: A solar cell with a bypass diode: (a) circuit diagram, (b) circuit diagram with solar cell replaced with equivalent circuit.

The purpose of this example is to illustrate the functioning of a bypass diode connected across a solar cell (see Fig. 1 (a)). In Fig. 1 (b), the same circuit is shown with the solar cell replaced with its equivalent circuit which will help us to understand the various contributions to the total current (I_{total} in the figure). Note that the current source representing the photocurrent I_p and the diode D are the main components of the solar cell model. The "parasitic" elements, viz., the series resistance R_s (typically small) and the parallel resistance R_p (typically large) are also included for the sake of completeness. However, their contribution – the voltage drop across R_s and the current through R_p – is generally small, and we will ignore it in the following.

In Fig. 2, the solar cell current (I_C) and the bypass diode current (I_{BP}) are plotted as a function of the voltage V_a of Fig. 1. First, let us consider V_a to be positive. In this case, the bypass diode does not conduct (see the blue curve in the figure). When V_a is small, the current through the diode D in the solar cell model is also negligibly small, and $I_C \approx I_P$. As V_s increases, D starts conducting, and at some point, I_D becomes larger than I_P, making $I_C = I_p - I_D$ negative.

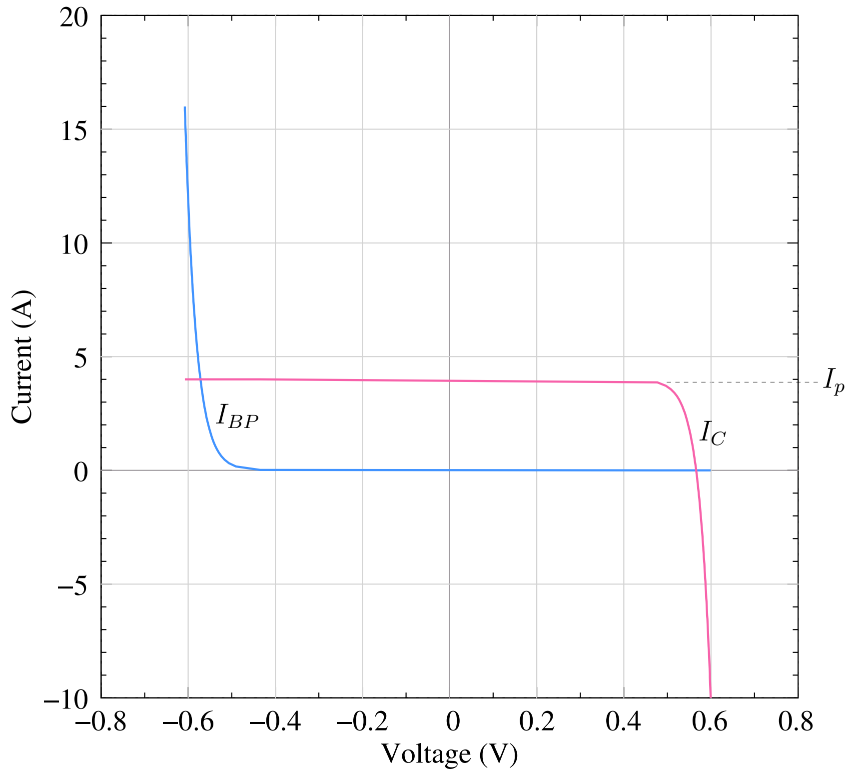

Figure 2: Solar cell current (I_C) and bypass diode current (I_{BP}) versus voltage (V_a in Fig. 1).

When V_a is negative, diode D is off, and $I_C \approx I_p$. When V_a (in magnitude) becomes greater than the turn-on voltage of the bypass diode, I_{BP} shoots up, as seen in the figure at $V_a \approx -0.6\,\text{V}$.

The total current $I_{\text{total}} = I_C + I_{BP}$ is plotted as a function of V_a in Fig. 3. A few specific points (A, B, C, D) are marked on the I-V curve, with the corresponding current paths shown in Fig. 4. Let us summarise the conditions at each of these points.

* Point A: $I_{\text{total}} \approx I_p$, V_a is positive but is not large enough for D to conduct. Since $V_a < 0\,\text{V}$, D_{BP} is off.

* Point B: V_a is positive and is large enough for D to turn on, and $I_{\text{total}} \approx I_p - I_D$ is less than I_p.

* Point C: V_a is positive and is large enough to make I_D greater than I_p. As a result, $I_{\text{total}} \approx I_p - I_D$ is negative. (This condition is not of practical interest since the solar cell is now absorbing power rather than delivering it.)

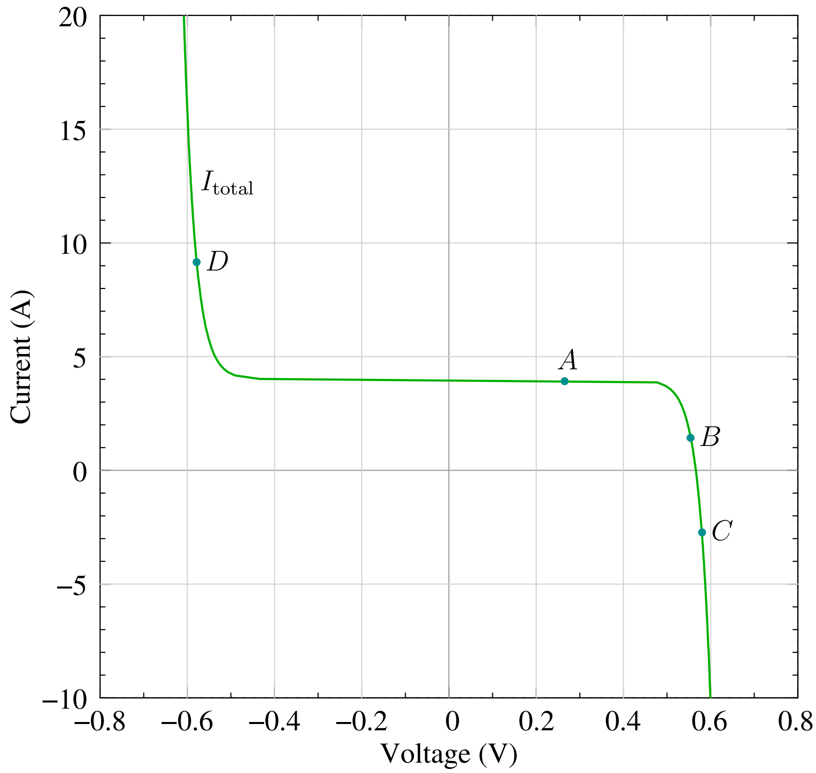

Figure 3: Total current ($I_{\text{total}} = I_C + I_{BP}$) versus voltage ($V_a$ in Fig. 1).

* Point D: The total current is larger than I_p. For this to happen, the bypass diode must turn on, which means V_a must be sufficiently negative. Although the solar cell absorbs power rather than delivering it, this condition is actually of great interest in practice. Without the bypass diode, the PV cell can conduct a current greater than its I_p only by undergoing reverse breakdown. This is an undesirable situation leading to excessive power disspiation ("hot spot") in the PV cell or module.

Exercise Set

1. How will the I-V curve (i.e., I_{total} versus V_a) change if the reverse saturation current of D_{BP} is reduced by a factor of 10. Verify with simulation.

2. How will the I-V curve change if the temperature is increased by 30° C? Verify with simulation.

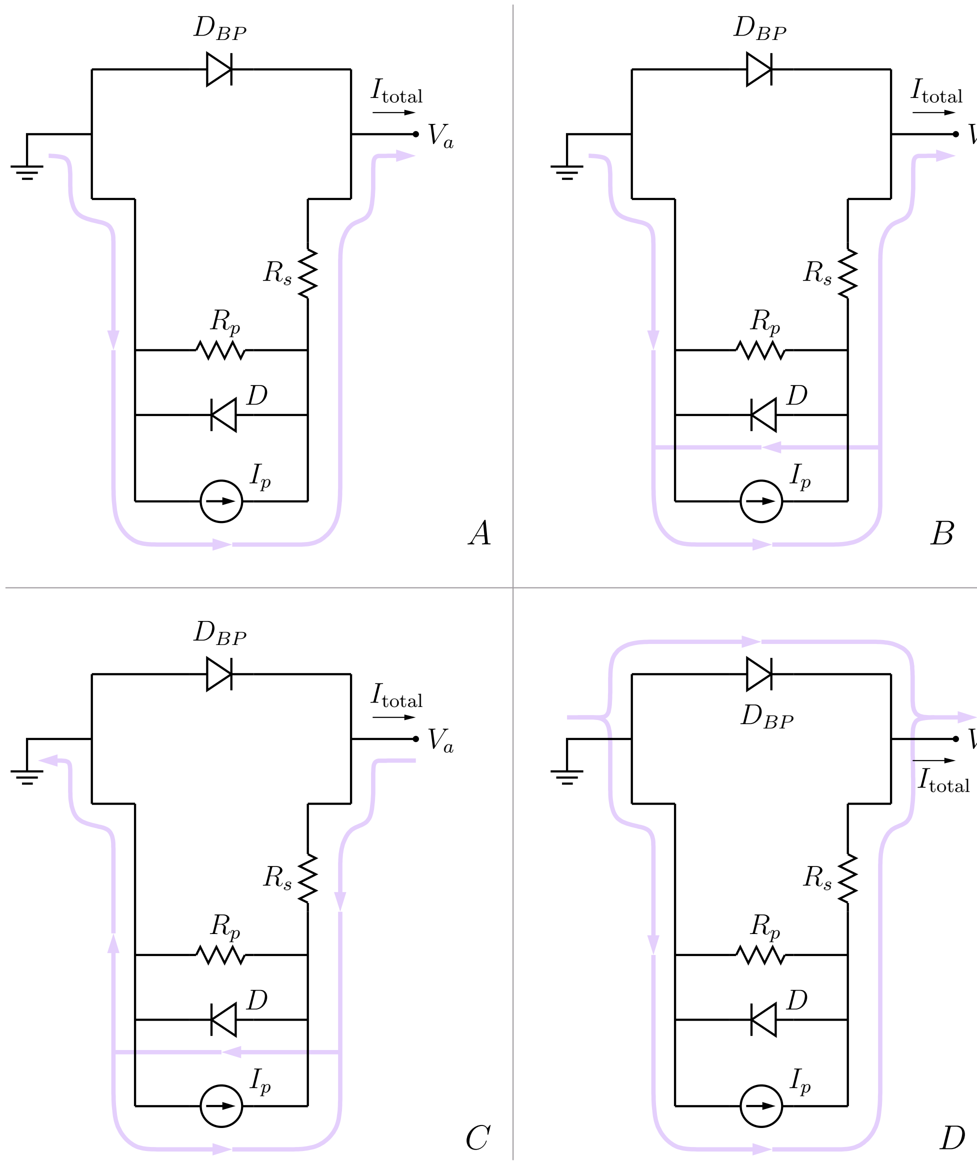

Figure 4: Current paths corresponding to the four points marked A, B, C, D in Fig. 3.

References

1. L. Castaner and S. Silvestre, *Modelling Photovoltaic Systems with PSpice,* John Wiley and Sons, 2002.

2. C. S. Solanki, *Solar Photovoltaics: Fundamentals, Technologies, and Applications,* Prentice-Hall India, 2011.