16.2.4 Translation Equations to Reference Conditions

The most basic translation equations for a solar cell are based on the diode model with series and shunt resistances discussed in Chapters 3 and 7. This model has been extended to modules by combining them in series and parallel combinations [55].

To a first order, short-circuit current (I_{SC}), open-circuit voltage (V_{OC}), P_{max}, and fill factor (FF) are linear with temperature, whereas the current is linear with E_{tot} [49, 56–60]. These linear translation equations allow the performance under standard reference conditions to be translated to other conditions for energy-based rating methods. Typical temperature coefficients for various PV technologies are summarized in Table 16.5 and Figure 16.5.

A set of translation equations for current and voltage based on the work of Sandstrom has been implemented in consensus standards [61, 62]. These equations translate the entire current versus voltage (I–V) curve for temperature and irradiance. Following the notation of the international standard in Reference [62], the following equations allow one to translate the current I_1 and voltage V_1 measured from temperature T_1 to T_2 and irradiance E_1 to E_2:

$$I_2 = I_1 + I_{SC1}\left(\frac{E_2}{E_1} - 1\right) + \alpha(T_2 - T_1) \tag{16.4}$$

$$V_2 = V_1 - R_s(I_2 - I_1) - I_2 K(T_2 - T_1) + \beta(T_2 - T_1), \tag{16.5}$$

where α and β are the temperature coefficients, R_s is the series resistance, and K is a curve-shape correction factor. Applying equations (16.4) and (16.5) at a fixed irradiance

Table 16.5 Typical Si solar cell temperature coefficients [57]

Type	$-V_{OC}$ [ppm/°C]	I_{SC} [ppm/°C]	$-FF$ [ppm/°C]	$-P_{max}$ [ppm/°C]
Si cells & modules	2400–4500	400–980	940–1700	2600–5500

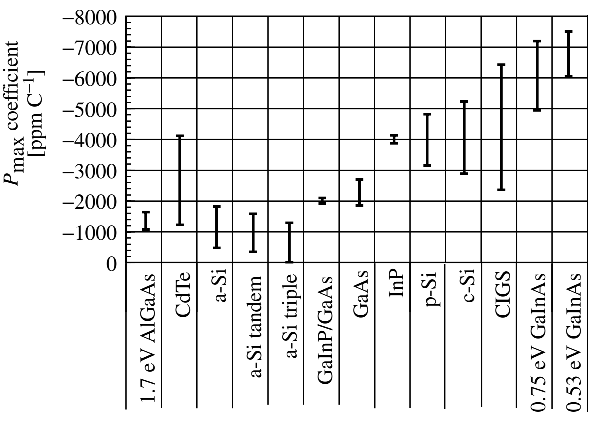

Figure 16.5 Typical P_{max} temperature coefficients of various PV technologies [57]