($E_2 = E_1$) and assuming no series resistance ($R_s = 0$), the value of K that best translates the $I-V$ characteristics for temperature is determined.

Translation equations for I_{SC}, V_{OC}, V_{max}, and I_{max} as a function of E_{tot}, T_c, absolute air mass (AM_a), and angle of incidence (AOI) based on multiple regression analysis of field data have been proposed by King [63]:

$$I_{SC}(E, T_c, AM_a, AOI) = (E/E_0) f_1(AM_a) f_2(AOI)[I_{SC0} + \alpha_{I_{SC}}(T_c - T_o)] \quad (16.6)$$

$$E_e = I_{SC}(E, T_c = T_0, AM_a, AOI)/I_{SC0} \quad (16.7)$$

$$I_{mp}(E_e, T_c) = C_0 + E_{ec}[C_1 + \alpha_{I_{mp}}(T_c - T_0)] \quad (16.8)$$

$$V_{OC}(E_e, \mathrm{i}) = V_{OC0} + C_2 \ln(E_e) + \beta_{V_{OC}}(T_c - T_0) \quad (16.9)$$

$$V_{mp}(E_e, T_c) = V_{mp0} + C_3 \ln(E_e) + C_4[\ln(E_e)]^2 + \beta_{V_{mp}}(T_c - T_0) \quad (16.10)$$

$$I_{SC0} = I_{SC}(E = E_0, T_c = T_0, AM_a = 1.5, AOI = 0^\circ) \quad (16.11)$$

$$V_{OC0} = V_{OC}(E_e = 1, T_c = T_0) \quad (16.12)$$

$$V_{mp0} = V_{mp}(E_e = 1, T_c = T_0) \quad (16.13)$$

$$f_2 = \frac{\dfrac{E_0}{I_{SC0}} I_{SC}(AM_a = 1.5, T_c = T_0) - E_{diff}}{E_{dir}\cos(\theta)}, \quad (16.14)$$

where E is the plane-of-array solar irradiance, E_e is the effective irradiance in units of suns, E_0 is the one-sun irradiance of 1000 Wm^{-2}, E_{diff} is the diffuse irradiance in the plane of the module, E_{dir} is the direct-normal irradiance, and AOI is the solar angle of incidence on the module; T_c is the temperature of the cells inside the module, T_0 is the module reference temperature, and $\alpha_{I_{SC}}$, α_{Imp}, $\beta_{V_{OC}}$, and $\beta_{V_{mp}}$ are the temperature coefficients of I_{SC}, I_{mp}, V_{OC}, and V_{mp}, respectively. These temperature coefficients are in absolute units so they will vary with the size of the PV device, the number of devices in series, or the number of devices in parallel. The pressure-corrected relative optical air mass AM_a can be written as [64]

$$AM_a = \frac{P}{P_0}[\cos(\theta) + 0.50572(96.07995^\circ - \theta)^{-1.6364}]^{-1}, \quad (16.15)$$

where P is the barometric pressure, P_0 is the pressure at sea level, and θ is the angle between the sun and zenith in degrees. The function $f_1(AM_a)$ is empirically obtained from the temperature- and irradiance-corrected I_{SC} versus air mass and assumes that the only spectral dependence is the zenith angle. Data are collected over a range of irradiances, incident angles, air masses, and temperatures and a multiple regression analysis is applied. These translation equations have been compared with simple linear translation equations derived from simulator-based measurements for several modules using outdoor data [49]. These translation equations give similar results to equation (16.3) when temperature, maximum-power tracking, and spectral issues are considered [48]. Other translation equations for current and voltage are possible [16, 65].