- The short-circuit current of a solar cell depends exclusively and linearly on the irradiance. That is,

$$I_{SC}(G) = \frac{I^*_{SC}}{G^*} G_{eff} \tag{20.68}$$

where G_{eff} is the "effective" irradiance. This concept must take into consideration the optical effects related to solar angle of incidence, as described in Section 20.7. Effects, as described by equations (20.46–20.59), are as follows:

- The open-circuit voltage of a module depends exclusively on the temperature of the solar cells T_c. The voltage decreases linearly with increasing temperature. Hence,

$$V_{OC}(T_c) = V^*_{OC} + (T_c - T^*_c)\frac{dV_{OC}}{dT_c} \tag{20.69}$$

where the voltage temperature coefficient, dV_{OC}/dT_c is negative. The measurement of this parameter used to be included in PV modules characterisation standards [51, 56] and the corresponding value must, in principle, be also included on the manufacturer's data sheets. For crystalline silicon cells, dV_{OC}/dT_c is typically −2.3 mV per °C and per cell.

- The series resistance is a property of the solar cells, unaffected by the operating conditions.
- The operating temperature of the solar cell above ambient is roughly proportional to the incident irradiance. That is,

$$T_c = T_a + C_t G_{eff} \tag{20.70}$$

where the constant C_t has the value:

$$C_t = \frac{NOCT(^\circ C) - 20}{800\ W/m^2} \tag{20.71}$$

The values of *NOCT* for modules currently on the market varies from about 42 to 46°C, implying a value of C_t between 0.027 and 0.032°C/(W/m^2). When *NOCT* is unknown, it is reasonable to approximate $C_t = 0.030$°C/(W/m^2). This *NOCT* value corresponds to mounting schemes allowing the free air convection in both sides of the PV modules, which cannot be the case on roof-mounting arrays, that restrict some of the airflow. Then, it has been shown [57] that the *NOCT* increases by about 17°C if some kind of back ventilation is still allowed and up to 35°C if the modules are mounted directly on a highly insulated roof.

Example: To illustrate the use and the usefulness of the equations of the above sections, we shall analyse the electrical behaviour of a PV generator rated at 1780 W (STC), made up of 40 modules, arranged 10 in series × 4 in parallel. The conditions of operation are $G_{eff} = 700$ Wm^{-2} and $T_a = 34$°C. It is known that the modules have the following characteristics under STC: $I^*_{SC} = 3$ A, $V^*_{OC} = 19.8$ V and $P^*_M = 44.5$ W. Further, it is known that each module consists of 33 cells connected in series and that *NOCT* = 43°C.

The calculations consist of the following steps:

1. Determination of the characteristic parameters of the cells that make up the generator under STC (equations 20.63–20.67):