Description of WATSUN-PV model

ESP-r's WATSUN-PV model has an empirical basis and calculates a photovoltaic (PV) cell's short-circuit current and open-circuit voltage as follows:

$$I_{sc} = I_{sc,ref} \frac{E_{T,eff}}{E_{ref}} \left[1 + \alpha (T_c - T_{c,ref})\right] \quad (1)$$

$$V_{oc} = V_{oc,ref} \left[1 - \gamma \left(T_c - T_{c,ref}\right)\right] \cdot \max\left\{0{,}1 + \beta \ln\left[\frac{E_{T,eff}}{E_{ref}}\right]\right. \quad (2)$$

where the subscript *ref* indicates reference conditions, $E_{T,eff}$ is the effective irradiance incident on the module, which includes the beam and diffuse components of solar radiation, taking into account the reflectance of the front surface of the module. T_c is the cell temperatures and α, γ and β are empirical coefficients. The empirical coefficients in equations 1 and 2 are provided in the specifications for many PV modules. Standard reference conditions are $E_{ref} = 1000$ W/m^2 and $T_{c,ref} = 25$°C.

The maximum power produced by the PV cell is calculated as follows:

$$P_{mp} = I_{mp,ref} \cdot V_{mp,ref} \left[\frac{I_{sc} \cdot V_{oc}}{I_{sc,ref} \cdot V_{oc,ref}}\right] \quad (3)$$

The maximum power point current, $I_{mp,ref}$, and the maximum power point voltage, $V_{mp,ref}$, are available from manufacturers' specifications.

In ESP-r, the PV module surface is represented as a multi-layered construction consisting of several layers. Each layer is represented with one or more nodes. One node within the surface is identified as a special material node; this node represents the location of the PV cells within the module. The cell temperature T_c is determined by considering the energy balance of the special material node. It should be noted that the solar radiation absorbed by the special material node is reduced by the power generated from the node.

In addition to the identification of the node within the PV module surface that represents the PV cell, ESP-r's WATSUN-PV model requires a total of 16 inputs:

Open circuit voltage at ref (V)
Short circuit current at ref (A)
Voltage at maximum power point at ref (V)
Current at maximum power point at ref (A)
Reference insolation (W/m2)
Reference temperature (K)
Temperature coefficient of Isc (/K)
Temperature coefficient of Voc (/K)
Coefficient of logarithm of irradiance for Voc (-)

Number of series connected cells (not modules) (-)
Number of parallel connected branches (-)
Number of modules in surface (-)
Load type (0-maximum power, 1-fixed V)
Load value - voltage (V)
Shading treatment (0-def, 1-prop, 2-total, 3-diff.)
Miscellaneous loss factor (-)